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SKY & SPACE

The Only Astronomy & Space Magazine for Australia & NZ

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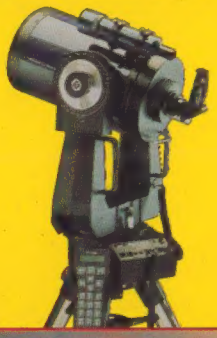

- Re-live the first manned mission to the Moon
- Australia's plans for a 21st Century space programme
- How to take better astrophotos of the night sky

Jupiter's Comet Crash

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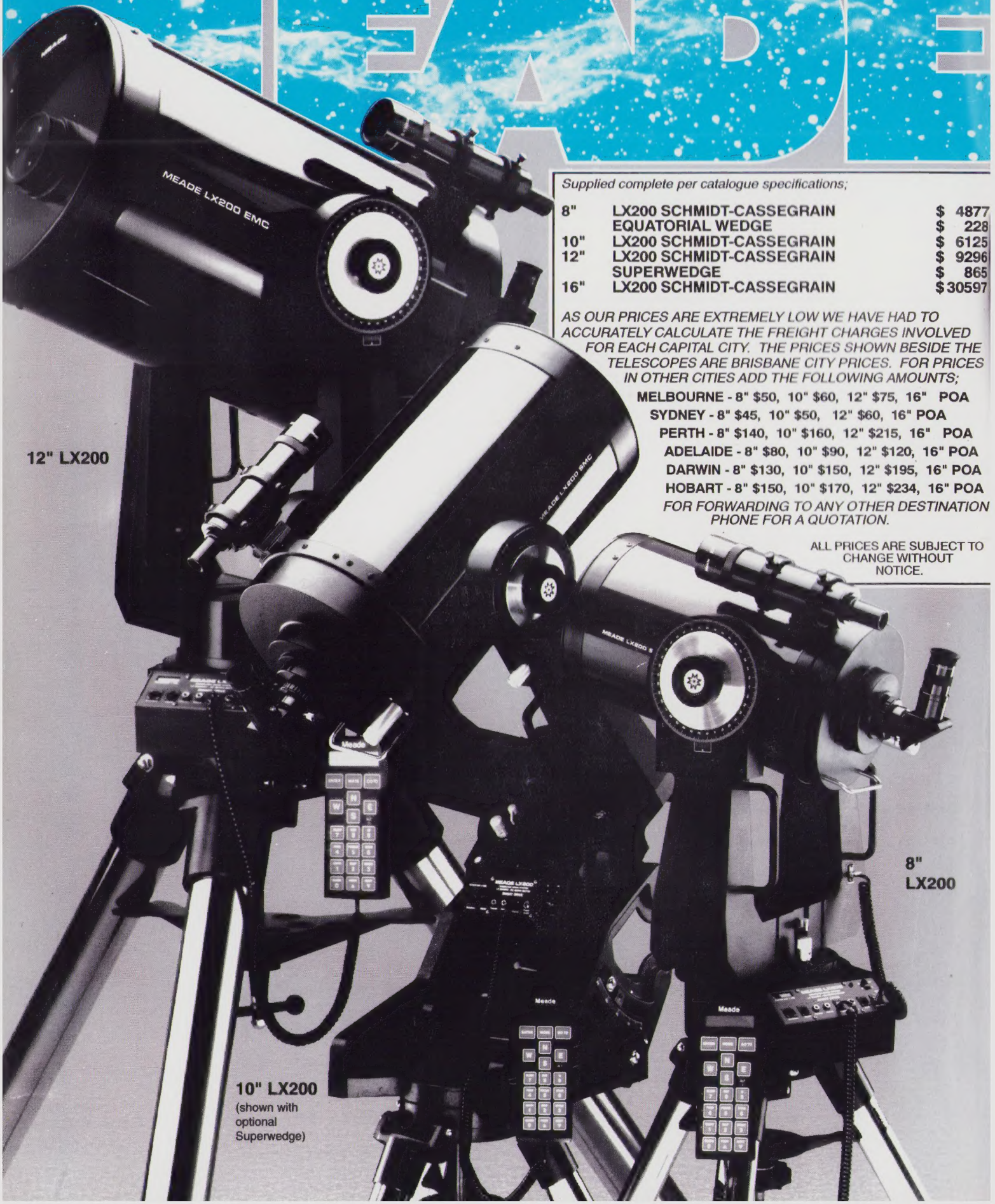

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12" LX200

8" LX200

10" LX200
(shown with optional Superwedge)

LX200 SCHMIDT-CASSEGRAINS:
New Technical Advances for 1994.

Six new technical advances that extend Meade's position at the leading edge of telescope technology:

1. 18-volt Dual-Axis Drive Systems

—All Meade 8", 10", and 12" LX200's now include **18-volt DC power systems,** superseding the previous 12-volt systems, with the result that **LX200 motor torques are increased by about 60%** over previous models. Combined with new, more efficient DC motor electronics, these powerful, high-torque drives, on both telescope axes, yield a level of drive smoothness heretofore unavailable on any commercial telescope.

2. Ultra-reliable Electronic Systems

—Recent electronic refinements in the main circuit boards, the hand controller, and in the control panel electronics have made Meade's new advanced LX200's more reliable than ever before. State-of-the-art improvements in microcircuitry, combined with *thousands* of hours of laboratory and field testing, result in **the most trouble-free serious telescopes ever manufactured.**

3. New *Version 3.20* Software

—As recently announced, Meade *Version 3.20* software is the very latest in telescope operating systems and permits **quick (less than 10 seconds!) 2-star alignment** of the LX200 in the altazimuth mode, without requiring your latitude or longitude, without even leveling the tripod. Just use 2 easy-to-find reference stars and the telescope tracks and actuates GO TO with extreme precision.

4. Software Library Options

Included with every LX200 is a basic 747-object database of the finest deep-space objects, reference stars, and the 8 major planets. *Version 3.20* LX200 software allows for two new optional object libraries:

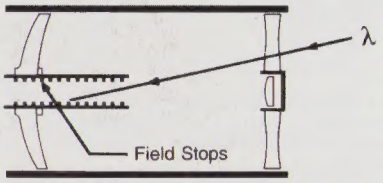
—**Library Option 1:** An object database of **10,600** celestial objects taken from the Messier, NGC, and IC catalogs. Available at **$199.65.**

—**Library Option 2:** An object database of **64,350** celestial objects, including the 10,600 objects of Library Option 1, above. Available at **$285.70.**

*For safety reasons AC-powered personal computers should be used indoors only.

5. PC-Interface Capability

Meade AstroSearch/200™ sky software permits the interface of a personal computer (PC) to your LX200. Just load Meade AstroSearch/200 software into your PC, connect the PC* to the LX200's PC port (located on the telescope's power panel) and you're ready to **point-and-click on any of 45,000 planetary, deep-space, or stellar objects** now visible on the PC display. As you point-and-click, the LX200 slews at high-speed (up to 8°/second) simultaneously on both axes, precisely centering the object in the field of view. **The Meade AstroSearch/200 celestial software package, supplied on 3.5" discs for Windows™ 3.1 or higher, is available from Meade dealers at $159.60..**



Field-stops *(arrow)*, now included on Meade 8", 10" and 12" Schmidt-Cassegrains, significantly increase image contrast by effectively blocking off-axis stray light rays, λ.

AN UNBELIEVABLE FREE OFFER!!!

FOR A LIMITED TIME ONLY WHEN YOU BUY A MEADE SCHMIDT CASSEGRAIN TELESCOPE YOU WILL RECEIVE FREE

2 X SERIES 4000 6.4mm AND A 9.7mm SUPER PLOSSL EYEPIECES
1 X SERIES 4000 #140 BARLOW LENS
1 X T-ADAPTER
1 X 64,350 OBJECT LIBRARY

THAT'S $783.00 WORTH OF ACCESSORIES ABSOLUTELY FREE!!

6. Contrast-Enhancing Field Stops

—All Meade 8", 10", and 12" Schmidt-Cassegrains now include a series of computer-optimized internal field stops, for greater rejection of unwanted stray light than ever before possible. These field stops, machined into the inside-diameter surface of the primary-mirror baffle tube *(see diagram)*, **significantly increase lunar, planetary, and deep-space image contrast,** compared to SCT's not so equipped.

Plus all of the features that have already made Meade® LX200's the largest-selling serious telescopes in the world:

■ **Legendary Meade Super Multi-Coated (EMC) Schmidt-Cassegrain Optics** —The finest SC optics available, optics that yield razor-sharp stellar images and high-resolution observing of the Moon, planets, and deep-space.

■ **Heavy-Duty Fork Mounts**—The largest, most rigid in the industry, complemented by large 4"-diameter polar ball bearings and by DC servo-motor-driven worm gears on both telescope axes.

■ **Four-speed Drives on both Telescope Axes**—Including photo-guiding (at **2x** sidereal rate); image centering and microslewing in the main telescope (at **32x** sidereal rate); image centering in the viewfinder (at **2**°/sec.); or fast-slew of the main telescope across the skies (at up to **8**°/sec.).

■ **Digital Readouts**—On both axes, read from the keypad hand controller.

■ **GO TO Capability**—Enter the RA and Dec of an object into the keypad hand controller, press GO TO, and the telescope slews to the object at up to 8°/sec., centering it in the field.

■ **747-Object Built-in Library**—Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, reference stars), or one of the 8 planets (from Mercury to Pluto), press GO TO, and the telescope slews at up to 8°/sec., centering the object in the field.

■ **Permanently Programmable Smart Drive™** —Capable of reducing periodic drive errors to 5 arc. secs. or less, an observatory standard.

Specifications: 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 SC optical tube assembly with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; keypad handheld controller with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cord and adapter for telescope operation from 240v.AC (DC capability for operation from auto cigarette lighter plug available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism (8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (8", 10") or giant field tripod (12"); foam-fitted carrying case; complete operating instructions.

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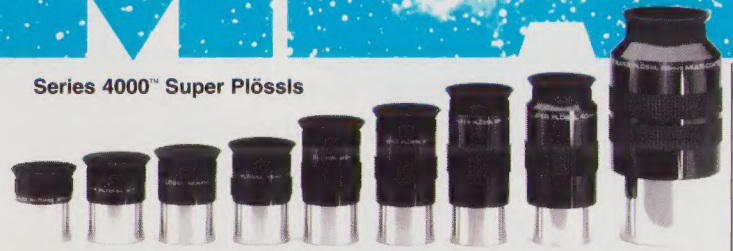
WORLD'S LEADING MANUFACTURER OF ASTRONOMICAL TELESCOPES FOR THE SERIOUS AMATEUR.

MEADE

EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls



Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types for 1994, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):
6.4, 9.7, 12.4, 15, 20, 26mm each: **$138.50**
9.7: $148.50
32mm: $171.95 40mm: $209.25
56mm: $401.40

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astro-photography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$276.75

Series 4000™ Super Wide Angle

For exquisite wide-angle images at low-to-medium powers, ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8, 18, and 24.5mm are superb complements to the #140 Barlow.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $235.70 18mm: $256.00 24.5mm: $346.85**
32mm (2"): $404.85 40mm (2"): $581.65

Series 4000™ Ultra Wide Angle

The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)–
4.7mm: $311.20 6.7mm: $392.85
8.8mm (1.25"/2"): $506.60 14mm (1.25"/2"): $634.20

Series 4000™ #140 2x Apochromatic Barlow Lens

The most advanced Barlow Lens available for commercial telescopes; includes 3-element, air-spaced optics, multi-coated. Unmatched in image resolution, contrast and color correction. Accepts 1.25" eyepieces. Lens dia. 28mm; clear aperture 26mm.

$170.25

Series 3000™ Plössls

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each:
$85.15

Series 3000™ Plössl 40mm

A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

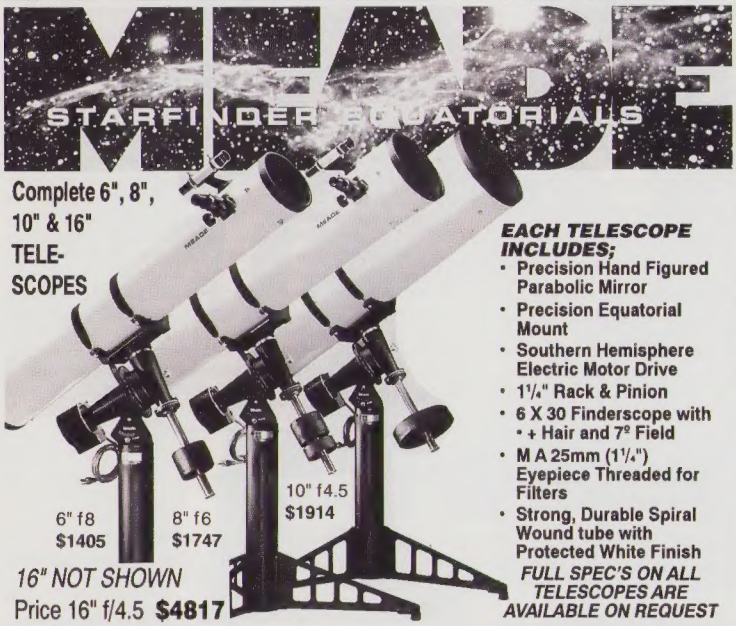
$143.75

Series 4000 Photo-Visual Color Filters (1.25")

Made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$27.55**

Moon Filter #ND96–Reduces brightness by 87%. **$33.95**
Set #1–4 filters: #12, #23A, #58, #80A **$106.40**
Set #2–4 filters: #11, #25A, #47, #82A **$106.40**
Set #3–4 filters: #8, #21, #38A, #56 **$106.40**
Sets #1 & #2–8 filters **$191.55**
Sets #1, #2, & #3–12 filters **$276.75**



EACH TELESCOPE INCLUDES;

- Precision Hand Figured Parabolic Mirror
- Precision Equatorial Mount
- Southern Hemisphere Electric Motor Drive
- 1¼" Rack & Pinion
- 6 X 30 Finderscope with • + Hair and 7° Field
- M A 25mm (1¼") Eyepiece Threaded for Filters
- Strong, Durable Spiral Wound tube with Protected White Finish

FULL SPEC'S ON ALL TELESCOPES ARE AVAILABLE ON REQUEST

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PHONE ORDERS OR MAIL ORDERS ARE WELCOME. WE CAN DELIVER TO ANY LOCATION IN AUSTRALIA FROM ANY ONE OF OUR STORES AT VERY COMPETITIVE PRICES. JUST PICK UP YOUR PHONE OR WRITE TO YOUR NEAREST YORK OPTICAL AND SCIENTIFIC STORE. WE ACCEPT BANKCARD, MASTERCARD AND VISACARD. PERSONAL CHEQUES ARE ALSO ACCEPTED BUT ALLOW AT LEAST 7 DAYS FOR CLEARANCE.

ACCESSORIES: TO COVER FREIGHT & PACKING ON ANY SINGLE ITEM ADD $6 TOTHE PRICES SHOWN. FOR EACH ADDITIONAL ITEM TO BE INCLUDED INTHE SAME SHIPMENT ADD AN ADDITIONAL $2.50.

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MELBOURNE -	6" $35,	8" $40,	10" $50,	12" $60, 16" $80
SYDNEY -	6" $30,	8" $35,	10" $40,	12" $50, 16" $65
PERTH -	6" $85,	8" $95,	10" $120,	12" $180, 16" $230
ADELAIDE -	6" $50,	8" $60,	10" $70,	12" $105, 16" $130
DARWIN -	6" $80,	8" $90,	10" $110,	12" $160, 16" $210
HOBART -	6" $90,	8" $100,	10" $120,	12" $200, 16" $250

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World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25"

$276.75

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$234.15

MA 12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control.

$212.85

MA 12mm—Same as above but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

$170.25

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter.

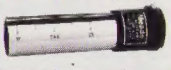
$212.85

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$95.70

2x-3x Variable Barlow (1.25")



#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25"

$119.65

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$95.70

Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, these 3-element Modified Achromatic eyepieces give sharp, faithful, well-corrected images of the moon, planets, and deep-space at an economical price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$59.90**

Camera Adapters (1.25" & .965")

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

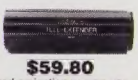
.965": $55.80 1.25": $59.80

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$79.75

Tele-Extenders



For Eyepiece-Projection photography with any Meade of Celestron SCT. Threads on to any eyepiece-holder. Use with T-mount for your camera.

$59.80

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos.

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.

$79.75

T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera.

$50.20

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Vol. 7 No. 4 OCTOBER 1994

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SPECIAL FEATURES

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One of Australia's most respected and loved astronomers, Dr David Allen, passed away in July. We present his last story.

16 One Giant Leap.
In this issue, we celebrate the historic Apollo 11 Moon landing. Kerrie Dougherty takes us step by step through the exciting and dangerous mission.

24 Pieces of another world.
Australia's Ross Taylor was in the thick of things during the first Moon landing. As leader of the chemical analysis team in NASA's Lunar Receiving Laboratory, Professor Taylor was responsible for finding out what the Moon is made of. This is his exciting story of those heady days in 1969.

Enter The SKY & SPACE - Meade Great Christmas Telescope Giveaway and *WIN A TELESCOPE valued at over $4,800!*
Plus lots of other prizes! See page 41 for details.

38 Man from the Moon.
As part of the world-wide celebrations of the 25th anniversary of the first Moon landing, NASA asked SKY & SPACE to organise all the festivities in Sydney, including the visit by Apollo astronaut, John Young. We present a complete run-down of the anniversary celebrations.

42 A National Space Program for the 1990s.
Australia has a long and distinguished history of space research, but we have only scratched the surface of our capabilities and opportunities. Head of the Australian Space Office, Malcolm Farrow, reports on where Australia is headed in space.

54 100,000 out . . .
How different would Planet Earth be if our world leaders could share the experiences of the astronauts? Would our perspectives change if we were able to view the Earth from 100,000 miles? In an exclusive extract from the new book, *The Greatest Adventure*, astronaut Mike Collins gives us his views.

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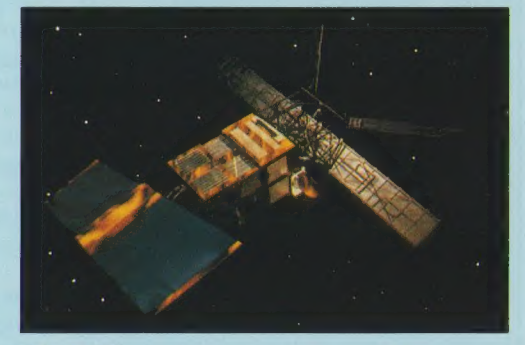

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ON THE COVER: The spectacular collision between comet Shoemaker-Levy 9 and the giant planet Jupiter has captured the world's attention. In this issue, we present a special 16-page lift-out supplement detailing the exciting week of the impacts, complete with stunning colour photographs from around the world. (Hubble Space Telescope picture courtesy of NASA/STScI.)

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SKY & SPACE

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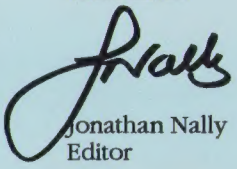
FROM THE EDITOR

Shoemaker surprises us all

The spectacular collision of comet Shoemaker-Levy 9 with Jupiter in July surprised everyone with its dramatic display of planetary fireworks. Huge explosions, gigantic dark spots in Jupiter's colourful cloud tops, and a dark belt around the planet are the legacy of this exciting period. Despite pessimistic predictions from most commentators that amateurs would miss out on the action, in the end anyone with even a small telescope could see the results of the comet collision! In this issue we present a special 16-page lift-out section on Jupiter's comet crash, complete with the first scientific results and lots of amazing pictures. We'll have lots more Jupiter/comet information over the coming issues, so keep reading these pages!

The other major happening for SKY & SPACE over recent months has been the celebrations of the 25th anniversary of the first manned landing on the Moon. SKY & SPACE was asked by NASA to organise all the anniversary festivities in Sydney, including the visit of NASA's senior astronaut Captain John Young (see page 38). Veteran of six space flights (more than any other astronaut or cosmonaut), Captain Young enthralled thousands of people throughout Sydney with tales of his flights and visions for the future. We are proud to have been a part of this exciting moment in history.

Clear skies!



Jonathan Nally
Editor

YOUR SAY . . .

An interest rekindled

Frank Bateson's article (August, 1993) made very interesting reading and took me back 25 years to when as a young boy I met Frank for the first time at a Royal Astronomical Society of New Zealand annual meeting in Whakatane. I remember looking in awe at this tall figure whom I had heard so much about from other, more senior members of the Astronomical Society. I was smitten by the astronomical bug in my early teens and with the help of Stan Walker, Brian Marino, Graham Loftus and Barry Menzies really became involved in the observation of variable stars.

I will always remember my father entering the conversation at that meeting when some of the members, including Frank, were talking about *Norton's* (the star atlas). To my surprise my father, who was only there for his son's benefit, said that he had an old Norton's but sold it some time ago and that he used to give me rides on it! There was stunned silence, Frank grinned at me and added, 'Yes, they were a good machine alright', and changed the subject. That's the kind of man Frank is. I don't think my father ever realised we were talking about a star atlas, not motor bikes.

I met Frank a few more times after that, and I still regard him as the most remarkable man I have ever met. I am indebted to him for infecting me with the enthusiasm and encouragement in our mutual love of astronomy.

I now live in the clear skies of central Queensland and my interest in the skies has been rekindled. I am in the process of putting together a telescope, forming an astronomy club and resurrecting my old variable star charts. Even after 20 years I can still recognise the fields of S Apodis, VW Hydri and a number of other fields. Who needs a camera?

John Clarke
North Rockhampton, Qld

Some lateral thinking

I am a relative newcomer to astronomy, having been interested in it for perhaps 25 years but not doing anything about it. I own a 3-inch f/15 refractor which I have unpacked from storage and actually observed Jupiter for the first time using it a couple of months ago. I am by trade a computer engineer and have read with great interest, Stephen Lee's Technical Tips in your June 1994 issue.

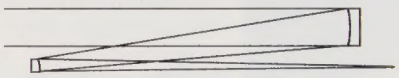
He discusses the issue of secondary obstruction in a Newtonian telescope.

Wouldn't it be possible to angle the primary mirror so that the reflected image actually goes off axis such that the secondary mirror would be placed outside of the field of view? I guess that I might be stirring up a hornet's nest but wouldn't it be feasible? I am not an optical engineer however I do realise that the primary mirror would have to change or perhaps a correcting lens would be necessary but then we would get a zero secondary obstruction.

Maybe this just shows up my ignorance of these matters, but perhaps a telescope of this nature may be possible to be built - maybe the cost of making an appropriate mirror and/or correction lens outweighs the advantages.

John Lowe
Telopea NSW

The system you describe is called a Schiefspiegler, which has two spherically-curved mirrors to focus the light. Schiefspieglers have long focal lengths, narrow fields of view and high magnification. You win the free subscription, Mr Lowe.



The Schiefspiegler telescope design.

A positive response

I must agree with Ian Beagrie (Your Say, June 1994), that it is sometimes difficult to defend the cost of space exploration to people who have no interest in it. I wonder why people pick on the space programme as being a 'waster of money?' Why shouldn't we give up sport, gambling, military expenditure or our beloved motor cars to feed the starving millions?

They seem to react to the loss of a spacecraft as if the 'millions of dollars' are being put into a capsule and jettisoned off into space. I prefer to explain to them that most of the money actually goes into employing scientists, engineers and other personnel, thus supporting their families. Space science opens up new fields of research and learning and has brought about great advances in computer technology, miniaturisation, weather monitoring and communications.

Manufacture of space hardware utilises both human and natural resources during months and even years before take-off. And then the information we gain gives us a deeper understanding of our place in the universe and will hopefully help people understand how important it is to look after our own little rock. Otherwise, who knows, Earth may one day end up just like Mars.

Lesa Moore
Kariong, NSW

Tropical telescopists

Congratulations on a first-class astronomical publication. I am writing on behalf of the Activities Department at Heron Island, in the Capricorn group of islands on the Great Barrier Reef.

One of our organised activities, 'Stargazing', involves pointing out to groups of guests the constellations in the night sky, and explaining the relevant legends behind them. Your magazine is particularly helpful in providing interesting new facts and figures for us to pass on to our eager visitors, such as the Shoemaker-Levy 9 article in April's 'Comet News', which dispelled an April Fool's Day prank that the comet was in fact going to cause Jupiter to explode!

The viewing conditions here are superb, as we have no light pollution and no atmospheric pollution - our island is 72 kilometres from the mainland. Maybe you should think about organising an astronomical field trip up here some time, it'd be well worth it!

Once again, thanks for a great publication that caters for rank amateurs like ourselves.

Jason Froud
Heron Island, Qld

Give us back our heroes

In view of all the media attention being given to Comet Shoemaker-Levy 9, I thought it necessary to express my opinion on something that has annoyed me for some time.

Recently I asked some people whom they thought discovered the comet. The response was, 'some guy named Shoemaker, I guess'. I then went on to inform them that the 'guy' was in fact a woman, Caroyln Shoemaker (not forgetting David Levy, of course). The point is that every interview I saw on TV or heard on radio was with Eugene Shoemaker (Carolyn's astronomer-husband) or David Levy or some totally unrelated scientist.

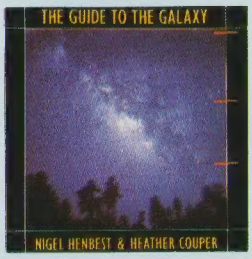
Where is Carolyn? We have so few female heroes. No-one for the young female student or scientist to look up to. Here is a woman who shows all the determination and willpower necessary to make real advances in her chosen field, and the media ignores her. When I was growing up it was Marie Curie and Albert Einstein that I had for my heroes. The young of today have no-one. No wonder they don't go into science! Give us back our heroes!

Theresa Mitchell
Berry, NSW

The writer of the best letter published in each issue will receive a free six-issue subscription to SKY & SPACE Magazine. Letters may be edited for brevity or clarity. Write to: The Editor, SKY & SPACE Magazine, 80 Ebley Street, Bondi Junction, NSW, 2022. We regret that due to high volume, we cannot individually answer all letters.

WIN A FREE BOOK!

Cambridge University Press have kindly provided a copy of the *The Guide to the Galaxy*, by Nigel Henbest and Heather Couper, for SKY & SPACE to give away to one lucky reader.



The Guide to the Galaxy introduces the nature and structure of our Galaxy as a whole, and covers black holes, globular clusters, star formation, supernovae, and more, all in non-technical language with a dazzling selection of colour photos.

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Mail, fax and phone orders are accepted - there is an order form on page 48.

Winner of the June issue prize, *Atlas of Neptune*, was Mr D. Galea, Altona Meadows, Vic.

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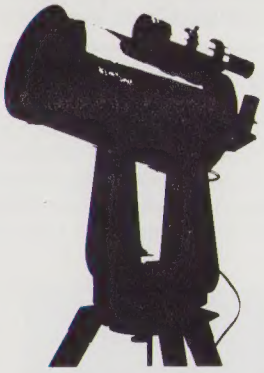

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The Moon is not a theme park.

Recent proposals by a US entrepreneur to land a small roving vehicle on the Moon and operate it by remote control as a theme park attraction, together with the sale of one of the former Soviet Union's Lunakhod Moon rovers, in situ, to a private collector, should be a matter of concern to everyone with an interest in astronomy, space history and the world's natural heritage.

Human activities on the Moon are governed by two United Nations treaties, the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies* (promulgated in 1967) and the *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies* (promulgated in 1979). In essence, these treaties establish that the Moon is neutral territory that belongs to the Earth as a whole, and not to any one nation. They not only bind the activities of the government agencies of the signatory states, but also the activities of private citizens of those states.

While neither of these treaties preclude commercial activities on the Moon, and both regrettably fail to make specific provision for safeguarding the historical evidence of the first lunar explorations, the spirit of the agreements supports the view that, like Antarctica, the Moon is a part of the Earth's natural heritage and the evidence of its early exploration is part of humanity's cultural heritage.

The sale of a Lunakhod vehicle, still on the Moon, to a private collector, via the Sotheby's auction held last December, sets a worrying precedent for artefacts of space history. The exploration of space is one of the great technological achievements of humanity and its artefacts are part of the common cultural heritage of the world. The Lunakhod sale has taken a piece of the world's cultural property, part of the evidence of the human exploration of the Moon, and turned it into a commercial item to be sold and traded like any other 'collectible'. It is the equivalent of selling one of the original copies of the Magna Carta, or Tutankhamen's funerary mask, or Mawson's Hut in the Antarctic to a private collector. Will we now see cash-strapped Russia treating the Moon (and possibly Mars or Venus) as a heritage milch cow, selling other in situ spacecraft as a way of raising funds?

Equally disturbing is the 'lunar rover as fun park ride' proposal announced recently in the United States. While there is at present no barrier to the commercial exploitation of the Moon, provided such exploitation does not contravene the UN treaties, the use of the Moon for such a non-productive purpose raises serious concerns. The operation of such a rover will provide neither scientific nor economic returns (except to the operator on Earth) to the world at large. It will however, provide the opportunity for potential damage to, or destruction of, natural features of the lunar surface and the sites of human exploration.

Tele-operation of remote vehicles is still a relatively new technology and it requires time and training to master the techniques in order to effectively operate the vehicle. This is especially the case with a vehicle on the Moon, where the time delay between a command and the response of the vehicle requires a readjustment of the reflexes. Lunakhod 2 was actually lost because its remote controller on Earth could not respond in time to the appearance of a boulder in its path. The mind boggles at the thought of some irresponsible person hooning around the lunar surface, knocking into natural formations, gouging up the terrain or, worse still, trundling over the Apollo 11 site and destroying the first human footprints! Imagine the outcry from environmental and natural heritage groups if a similar scheme were proposed for the Antarctic!

The Moon is not a theme park, the venue for another kind of 'Batman Adventure', nor is it a warehouse of space collectibles to be sold to the highest bidder. In order to protect its natural and space technology heritage for the whole world, it is time for the Earth's natural satellite to be protected by a World Heritage listing and/or the dedication of a lunar 'national park' under the auspices and protection of the United Nations. **Kerrie Dougherty.**

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A supernova full of surprises

Just when astronomers were beginning to think they had a good feel for what was going on in the vicinity of supernova 1987A (SN1987A), a new observation has revealed two extra rings of glowing material surrounding the exploded star.

The Hubble Space Telescope image shows three rings encircling the site of SN1987A, a star which exploded in February 1987.

The smaller, innermost ring has been known for some time. It has been interpreted by scientists as the interaction between pre-existing gas in the vicinity of the star and a shell of matter which was thrown off a few thousand years ago when a red giant star evolved into the blue star that eventually exploded. The fainter outer rings were also glimpsed by earth-based telescopes, but not with enough clarity or sensitivity to fully understand their nature.

The new Hubble picture clearly shows all three rings. The astronomers believe the small bright ring lies in a plane containing the supernova; the two other rings lie in front of and behind it. A possibility is that the rings might be 'painted' onto surrounding gas clouds by a beam of high-energy radiation or particles, emitted by a dense spinning body - a neutron star or black hole.

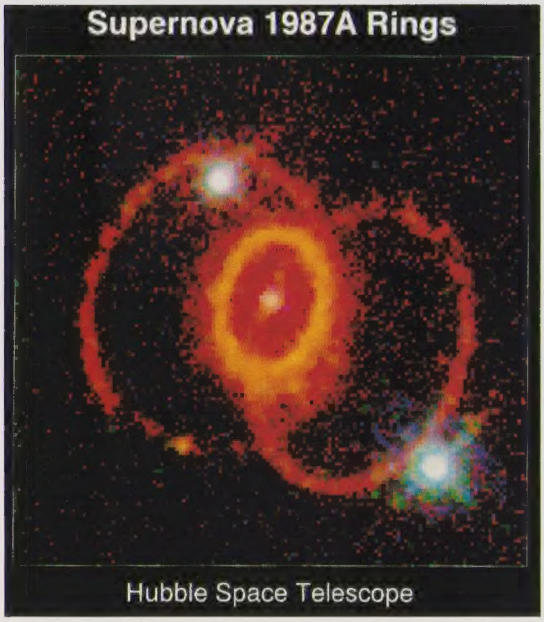
For the dense body theory to be correct, the object would need to have a companion star in a tight orbit around it. Material drawn off the companion would spiral onto the dense body's surface, be heated and blasted back into space in the form of two narrow jets of matter and radiation. If the dense body was wobbling (or precessing, a common feature of rotating bodies) the jets would trace out circles in the sky.

According to Dr Chris Burrows of the European Space Agency and the Space Telescope Science Institute, who made the observations in February this year, the Hubble images of the rings are quite unexpected. 'We have never seen anything behave like this before'.

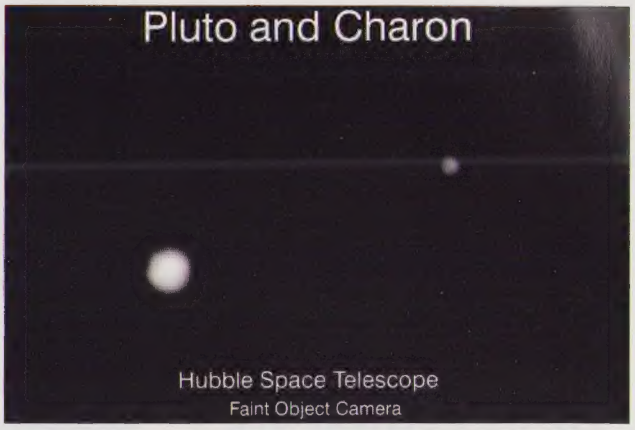
Burrows' came up with the spinning jet theory when he noticed that the two rings seem to be mirror images of each other. By connecting lines between common features in the rings, he found they intersected at a point in space some distance away from the supernova. Careful examination of the Hubble image showed a faint object, which may be the source of the beams, at the location he determined from the intersecting lines - about one-third of a light-year from the supernova.

Burrows thinks the jets are colliding with matter blown off from the supernova before it exploded; the matter would form an hourglass shape in space, due to the different speeds of matter ejected from the polar and equatorial regions of the star. The 'waist' of the hourglass - the inner ring - is illuminated by the radiation given off during the supernova explosion, whereas the outer rings are illuminated by the jets from the nearby dense, spinning body.

Burrows plans to keep an eye on this region during the coming years. If the dense body and its companion really exist, they should come face to face with the supernova's expanding cloud of ejected material sometime in the mid-1990s.



Left: *Supernova 1987A keeps the surprises coming. This new Hubble Space Telescope image by Dr Chris Burrows reveals three bright rings around the exploded star. Courtesy ESA/STScI and NASA.*



Above: *It seems that every year a new 'best ever' picture of Pluto and Charon is released. It may be quite a while before this latest Hubble Space Telescope image is beaten. Courtesy R. Albrecht, STECF/NASA.*

Pluto and Charon make a fine pair

Far out on the edge of the solar system, the tiny planet Pluto and its moon Charon circle slowly around the sun in their 248-year orbit.

Discovered in 1930 by US astronomer Clyde Tombaugh, Pluto remained almost a total mystery until the late 1970s when new observational techniques began to reveal some details of its make-up. Included in these new observations was the discovery of the planet's satellite, Charon, by James Christy in 1978. Other observational efforts gave tantalising glimpses of the planet's chemical composition and rotation axis.

In 1988 came the first direct evidence of Pluto's atmosphere; astronomers all over the world had their telescopes lined up on the distant point of light, to watch it pass in front of a background star (an event known as an occultation). Some astronomers were lucky enough to see the star's light fade slowly before being completely eclipsed by the planet. The slow fade was indicative of the light passing through a thin Plutonian atmosphere. The occultation also enabled the astronomers to refine their estimates of Pluto's size (see 'Spotting Pluto's changes', March 1992, page 44).

With the advent of the Hubble Space Telescope, astronomers gained a highly-capable observing tool above the Earth's turbulent, obscuring atmosphere. A Hubble image released in 1992 showed clearly for the first time Pluto and Charon separated in space (previous pictures

from ground-based telescopes were so blurry that the bodies seemed to merge into one). Now, with Hubble's optical capabilities fully restored, astronomers are seeing Pluto with unprecedented clarity.

The latest image shows Pluto and Charon as sharply defined discs. The observing team, led by the Space Telescope European Co-ordinating Facility's Dr Rudolf Albrecht, has used the image to measure the bodies' diameters to an accuracy of one percent: 2,320 kilometres for Pluto, and 1,270 kilometres for Charon.

The Hubble observations also show that Charon is bluer than Pluto, meaning the two world's have different surface compositions and structures. There is also a hint that Pluto may have a bright region around its equator and an overall smooth, reflective surface.

Further observations with Hubble will lead to greater clarity and an ability to perhaps see individual surface features on Pluto. And further down the track, NASA may send two small space probes to Pluto in the late 1990s (see 'Flying fast to Pluto', April 1994, page 26) to give us our first close-up glimpse of the tiny, icy world.

Getting the edge on Ida

The Galileo spacecraft captured this image of the edge of asteroid Ida about 46 seconds after its closest approach on August 28, 1993, from a range of only 2,480 kilometres (see the June issue, page 13). It is the highest resolution image ever taken of an asteroid's surface and shows detail at a scale of about 25 metres per picture element (pixel).

Since Ida's exact position in space was not well-known before the encounter, it was estimated that Galileo had only a fifty-fifty chance of capturing Ida in this frame. Fortunately, it did successfully image a part of the sunlit side of the asteroid.

Prominent in this view is a two-kilometre-deep 'valley' seen in profile on the edge, or limb. This limb profile, when combined with the picture of the whole asteroid will permit detailed refinement of Ida's shape.

Image courtesy of JPL/NASA

Have you heard an aurora?

Aurorae, commonly known as the 'northern or southern lights', are spectacular light shows in the sky resulting from the interaction of charged particles from the sun with the atmosphere of the Earth. Such events are quite frequently seen from high northern or southern latitudes: only during times of large disturbances to the Earth's magnetic field (such as March 13-14, 1989) are they seen from more equatorial latitudes.

Whilst they are a spectacular sight, less well known are intriguing reports of sounds being heard during auroral displays. As yet these sounds have not been recorded on any instrument, and to deepen the mystery, at times only some members of a group report hearing them. With such scant evidence, we must be wary about the reality of the phenomena.

Niel Davis, in the book *The Aurora Watcher's Handbook*, indicates that there are around 300 documented reports of auroral sound and a number of these come from technically trained people such as scientists. There is a good consistency in the description of the sound heard - at least 80 percent mention the letter 's' in the description and most report that the sound is a variable or undulating hissing, swishing, whooshing or crackling noise. Descriptions include: 'the swishing of a taffeta skirt', 'burning grass', 'the sound of crumpled tissue lightly rubbed between the hands', and 'the sound of a comb being drawn through a woman's hair'.

The sounds last from a few seconds up to some tens of minutes and many reports indicate a combination of a hissing sound followed by a sharper crackling. In general the sounds were not loud, but were quite definitely able to be heard. In most cases all members of a group would hear the sounds but there are reports of not all members hearing them. There have also been cases where people separated by hundreds of metres have all heard the sounds.

An example of a report of auroral noise comes from Dr H.D. Curtis, astronomer in charge of the Labrador Station of the US Lick Observatory in 1906. The report was later published in the September 21 issue of the reputable journal *Science*:

'On several nights I heard faint swishing, crackling sounds, which I could only attribute to the Aurora. There were times when large, faintly luminous patches or 'curtains' passed rapidly over our camp; these seemed to be close, and not more than a few hundred feet above the ground, thought doubtless much higher. The faint hissing and crackling sounds were more in evidence as such luminous patches swept past us . . . I tried in vain to assign the sounds heard to some reasonable source other than the aurora, but was forced to exclude them as possible sources . . .'

Fact or fiction - the evidence of witnesses seems good but could they all

Noisy aurorae? Many people hear swishing sounds coming from these colourful curtains.

be responding to the same psychological phenomena. Without hard evidence such as a recording there is no way to be sure at present. And if the reports are real, there is the tricky problem of the mechanism by which the aurora, 60-80 kilometres above the Earth's surface, generates the sound which people hear. **Richard Thompson, Ionospheric Prediction Service.**

A galaxy with a black hole heart

Black holes have captured the public imagination like no other celestial body has done. These enigmatic objects are the end products of the life cycle of massive stars. When a star of about three solar masses or more, uses up all its nuclear fuel, it explodes as a supernova. The stellar core collapses under the intense pressure to such a degree that everything is squeezed into a single point - a black hole. The gravitational field of a black hole is so strong that once inside nothing, not even light, can escape.

The problem is, how do you find black holes? Since they don't shine with their own light, and any light which tries to reflect off one is simply drawn in and devoured, the only way to find one is to look for the effects it has on its surroundings. One of the best places to look for these effects is in the centre of 'active galaxies'.

The giant elliptical galaxy, M87, is about 50 million light-years away from us in the constellation Virgo. For many years, astronomers have suspected that a giant black hole may inhabit the centre of the M87, but finding solid evidence proved too hard; that is, until the Hubble Space Telescope came along. With Hubble's improved performance (following last year's repair mission), astronomers have been able to measure accurately the mass and velocity of stars in the galaxy's core.

'A massive black hole is actually the conservative explanation for what we see in M87. If it's not a black hole, it must be something even harder to understand with our present theories of astrophysics', says Dr Richard Harms of the Applied Research Corporation (Maryland, USA).

Below: *Solid evidence of a black hole? NASA's Hubble Space Telescope has revealed a spiral-shaped disc of gas in the core of the giant galaxy M87. By measuring the speed at which the disc rotates, astronomers are able to calculate the amount of mass required to keep the disc together and spinning so quickly. Their conclusion is that it must be a black hole, perhaps as heavy as three billion suns. There are too few stars in the region to account for the mass required by the observational evidence.*

The team, led by Dr Holland Ford of the Space Telescope Science Institute and the John Hopkins University (Maryland), have detected an enormous cloud of hydrogen gas in the form of a rotating disc in M87's centre. By measuring the speed at which the gas disc is spinning, using Newtonian physics the astronomers are able to determine the amount of matter required in the galactic core to account for the rapid spin. But when they count the number of stars in the region, it is clear that there simply are not enough stars to account for the rotation. The amount of mass required can only be explained by the presence of a black hole which weighs as much as perhaps three billion suns, but squeezed into a space no larger than our solar system.

Ford's team measured the rotation velocity by looking at the redshift and blueshift of opposite edges of the disc.

The next stage of their investigations is to make even more detailed observations of the core of M87 in order to refine the velocity measurements.

Are newborn stars giving birth to planets in Orion's clouds?

The Orion Nebula is the most famous in the night sky. Easily seen with the unaided eye under a dark sky, the Nebula (catalogue name M42) has been recognised for many years as being one of the best candidate regions for the formation of planetary systems. Hundreds of very young stars populate the region, and as planetary systems are thought to be born with their star, astronomers have been studying Orion intently for any signs of planetary formation.

Dr Robert O'Dell, of Rice University (Texas) used the Hubble Space Telescope in 1992 to examine 110 stars in the Orion cloud and found giant discs of dust around many of them. Dubbed 'proplyds' (for protoplanetary discs), these conglomerations of matter are thought to be an early stage in the process of forming planetary systems. Now, new observations with Hubble have revealed even more proplyds, leading O'Dell and his colleague Zheng Wen to believe that more than half of the stars have accompanying dust discs.

O'Dell's latest observations show that the objects are pancake-shaped discs,

***Above:** A small portion of the Orion Nebula, showing several 'proplyds' (protoplanetary discs) surrounding young stars. The gas and dust in the discs are the remnants of the formation of the star; some of the matter may evolve further to form planets. The dark body is a proplyd seen in silhouette against the bright nebular background. **Right:** A wider view of the Orion star-forming region - more than half of the stars probably are surrounded by dust discs. Courtesy C.R. O'Dell/Rice Uni./NASA.*

rather than the shells of dust believed by some astronomers. Each proplyd has a young star at its centre; O'Dell's measurements of only part of the mass of each proplyd shows that there is enough matter present to make an earth-like planet.

Current stellar theory has it that the Earth and the other planets of our solar system were formed out of a proplyd-like disc around 4.5 billion years ago. The Orion Nebula proplyds contain the same sorts of materials - carbon, silicates and other base constituents - as the planets in our solar system.

Some of the discs are seen to shine brightly, while others are seen in silhouette against the bright nebula background. Some of them were even bright enough to have been seen previously by ground-based optical and radio telescopes as stars. It wasn't until the Hubble observations that their true nature was revealed.

The discovery of the proplyds, and in particular their apparent abundance, lends credence to the intriguing possibility that planetary systems are common throughout the universe, and possibly life too.

The Orion star cluster is too young - less than a million years old - for any planets to have formed within the dust discs. Many of the stars are still to reach the mature 'main sequence' stage of their lives.

The only other confirmed planetary system to date, consists of three earth-sized bodies orbiting a neutron star 1,000 light-years away. Since the neutron star is the burned-out remnant from a stellar explosion, these planets might have formed at the end of the star's life, and so, are not a good indicator of the abundance of planetary systems like our own.

ASTRO NOTES

Wind and Polar delays. The US parts of the international Global Geospace Science (GGS) programme, the Wind and Polar spacecraft, have been delayed. NASA is reviewing some of the hardware in the light of the recent Mars Observer and NOAA-13 spacecraft failures. The Wind and Polar missions are part of a programme to study the interaction between the solar wind and the Earth's magnetic field.

Stellar heavyweight. The globular star cluster, Omega Centauri, is one of the best telescopic sights in the far southern sky. Nobody knows exactly how many stars it contains, but recent estimates run into the millions. Analysis of its motion through space indicate that it plows through our Milky Way galaxy in an elongated orbit. In a recent study, astronomers have measured the speeds at which 469 of the stars orbit around the cluster's centre. Using these measurements, they have determined the total mass of the cluster to be about 5 million times the mass of our sun, or more than ten times the mass of most other globulars. This puts it mid-way in mass between the Milky Way and the so-called dwarf spheroidal galaxies.

Our climate and the sun. Astronomers at Armagh Observatory in Northern Ireland have unearthed from the archives meteorological records from the late 18th and 19th centuries which appear to support a strong link between air temperatures and solar activity. The Armagh data reveal a close correspondence between the mean air temperature and the length of the solar sunspot cycle throughout the last 200 years. Though the average solar cycle last 11 years, there are considerable variations for individual cycles. Higher temperatures coincided with shorter cycles. Extremes in the cycle length around 1800 and 1850 were accompanied by extremes in the mean temperature at Armagh. 'One cannot help but be struck by the fact that 1846, the first year of the Great Famine in Ireland, was one of the warmest years on record at Armagh', says Dr John Butler.

Putting the tether together again. NASA and the Italian Space Agency (ASI) have confirmed the reflight of the Tethered Satellite System (TSS). The TSS is a 1.5-metre-diameter instrumented sphere which is deployed from the space shuttle on the end of a 22km tether and dragged through the upper atmosphere. The first TSS mission, in July 1992, was curtailed when the tether jammed in its reel deployer mechanism. The TSS is intended to study atmospheric regions at intermediate altitudes, between those of high altitude balloons and free-flying satellites.

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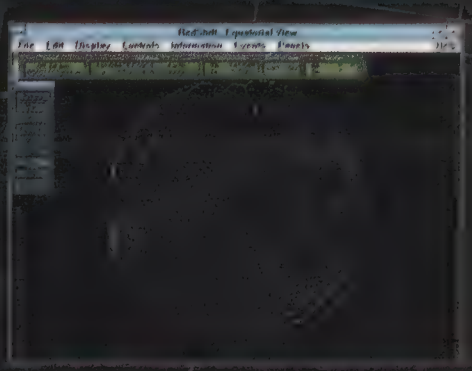

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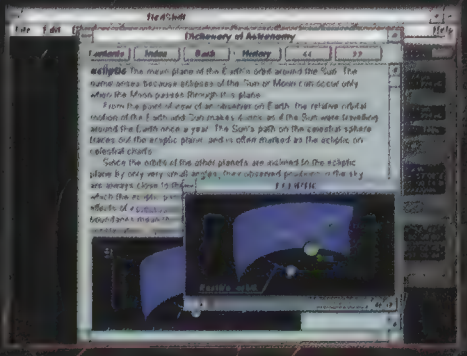

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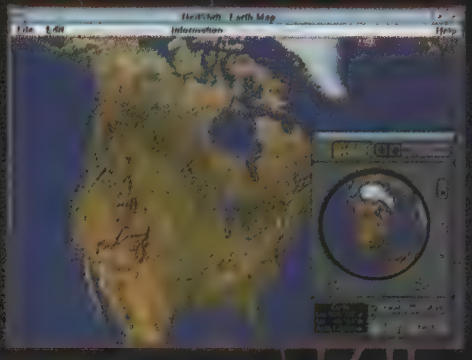

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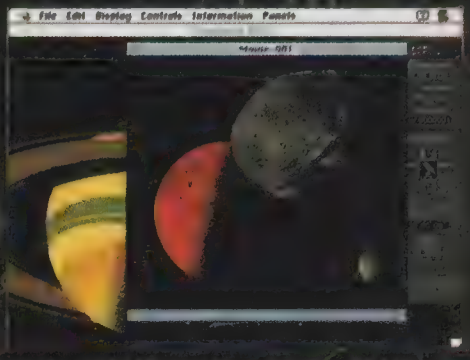

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Dr David Allen

July 30, 1946 - July 26, 1994

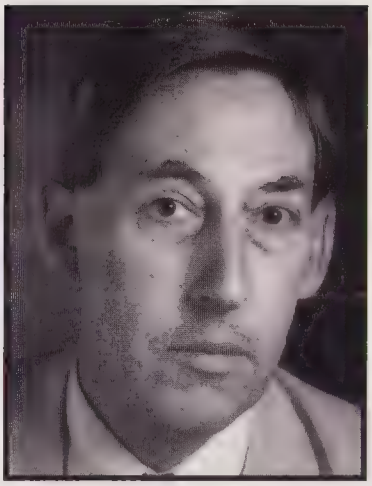
The astronomical community was saddened to learn of the death on July 26 of Dr David Allen, Senior Astronomer at the Anglo-Australian Observatory. David had been battling a terminal brain tumour for the better part of a year.

David joined the Anglo-Australian Observatory in 1975 as one of the first two UK Science Research Council Fellows. He was then appointed as an AAO Research Astronomer in 1977 and became the first and only permanent member of the Observatory's scientific staff in 1983.

David will be remembered for his enormous and uniquely broad contribution to the scientific life of the Observatory and to Australian astronomy in general. He was President of the Astronomical Society of Australia 1991-93 and was widely known for his popularisation of science, for which he won the Eureka Prize in 1993 (see Event Horizon, February 1994, page 8).

He was internationally recognised as one of the pioneers of infrared astronomy and was the key figure in the design and development of advanced infrared instrumentation for the Anglo-Australian Telescope, most recently IRIS. This instrument was critical to the success of the observations of cometary impacts on Jupiter in July. IRIS also won a series of engineering prizes, among which was a special, personal award to David from the Institution of Engineers, Australia.

Director of the Anglo-Australian Observatory, Dr Russell Cannon, recently wrote of David Allen, '. . . with his exceptionally wide knowledge across all of astronomy, his interest in the operations of the Observatory especially at the "sharp end" on Siding Spring Mountain, and his concern for the welfare of all staff and visitors, David in a very real sense *was* the AAO.'



Dr David Allen. (Photo: C. Bento/ Aust. Museum.)

We at SKY & SPACE are especially saddened, for David had been a great supporter of SKY & SPACE ever since our inception over seven years ago. We dedicate this issue of SKY & SPACE to the memory of our friend, David Allen.

My most memorable astronomical day

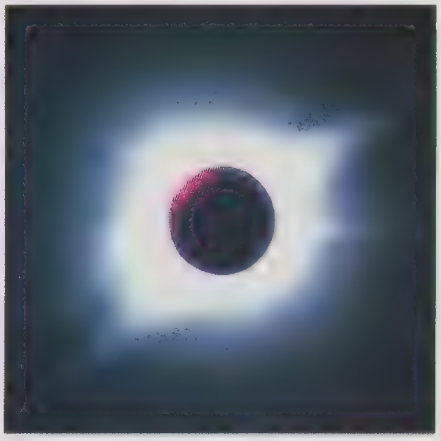
by David A. Allen

Nineteen-eighty-three. The trail rose steeply into the night. Through the still equatorial air came sounds of hooves ringing on stones, conveying a score of folk upwards to . . . well, none really knew what to. I preferred to walk, and though I was falling slowly behind the riders, I was content in my own world of darkness.

The night was clear, the sky velvet soft, as one finds at these latitudes. Artificial lights were almost nonexistent and the darkness was intense. I carried a torch, but as usual after half an hour under the stars I could see well enough without it.

The riders had all stopped at the top of the climb, to renew caffeine levels in a crowded hut. I glanced in and immediately decided to continue alone. The path curiously turned ninety degrees and began a steep descent. I couldn't tell why, but continued, puzzled. At the foot of the descent I entered a valley of mist, soft, beguiling and mysterious. Twilight was beginning to paint a clearer picture: two lines of cairns ran across a dusty plain: which trail to follow?

It wasn't too hard to choose, for ahead I could hear my quarry, rumbling, hissing. The walk through the ethereal mist towards that growling monster had an indescribably dream-like quality I shall never forget. Fifteen minutes later I was picking my way up a rubbly slope. I climbed above the valley of mists and presently I stood on the rim. The ground plummeted from my toes, and through the swirling smoke I could make out a gaping hole, backlit in red. Gas and smoke came out of the hole in a steady jet, with a grinding roar that reduced me to utter insignificance. The smoke plume rose several hundred metres above my head.



It was a stunning dawn. Gradually the stars dissolved into all the warm colours of the celestial palette. Mercury was one of the last to go. The rising column of smoke became a swirling silhouette in shades of brown, until slowly it too was lit by the advancing day, and the awe and wonder of the place gradually softened under the comfort of daylight. Below, the mists on the plain stirred and scurried, seeking hiding places among the stones to await the security of another night.

I returned to Surabaya. The streets of the city that would normally be bustling with life, were disarmingly deserted. A few police toured around to enforce a curfew. A sense of impending doom hung in the air. Back at the hotel I made my way to the roof and set up my camera. The first signs of the event so feared by the populace was already apparent; there was no stopping it now.

As the lighting grew weirder I was joined by an Indonesian, obviously an educated man who spoke excellent English. I showed him my protective viewing equipment and offered him its use. He declined. I explained when it would be safe to look. There, high on a rooftop and far from the eyes of authority I enjoyed a beautiful total eclipse of the sun while my Indonesian companion merely observed me observing it. 'I understand that it is safe,' he said, 'but my Government has decreed that no-one should look at the eclipse, so I will not.'

Those who have seen a total eclipse of the sun will know how great a spectacle, an emotional experience, it is. Yet I have trouble even now deciding which of the astronomical events of that day, totality or dawn from Mt Bromo, was the finest. S&S

David submitted this article shortly before the diagnosis of his illness last year. He died on July 26, 1994, aged 47.

One Giant Leap

by Kerrie Dougherty

Previous installments in our series on the Apollo programme have looked at the missions leading up to Apollo 11, setting the stage for the historic Moon landing flight. In this issue we celebrate the first lunar landing with an in-depth look at the epic voyage of Apollo 11.

Apollo 10's dress rehearsal mission in May 1969 had proved that a Moon landing was technically possible. Everything was now in readiness for the Apollo 11 mission to make history by placing the first human beings on another world. It would also effectively win the Space Race for the United States.

The crew of the flight that would make the first lunar landing comprised Neil Armstrong as Commander, Lunar Module pilot Edwin 'Buzz' Aldrin, and Command Module pilot Michael Collins. Armstrong had been a civilian NASA test pilot before being chosen as an astronaut, while Aldrin and Collins were both colonels in the US Air Force. All had previously flown missions during the Gemini program. The crew assignment for Apollo 11 had actually been made before it was designated as the flight to make the Moon landing, so it was, in a sense, the 'luck of the draw' that earned Armstrong, Aldrin and Collins their place in history!

On Wednesday July 16, 1969, everything was ready for the flight to the Moon. More than a million people lined the roadsides and over 3,000 boats jammed the rivers in the vicinity of Kennedy Space Centre, eager to watch the liftoff: some people camped out for weeks in advance to obtain one of the best viewing locations. Within the space centre itself, NASA played host to more than 6000 VIP guests, including former President Johnson, Vice-President Agnew and rocketry pioneer Hermann Oberth, who had originally inspired Wernher von Braun, the father of the American space programme. World interest in the event was intense, and over 1,750 journalists from around the globe were on hand to report on everything from what the astronauts ate for breakfast to the awesome statistics of the Saturn 5 rocket.

The Apollo 11 crew rose before dawn. After a 'low residue' breakfast, the astronauts began donning their space-suits about 5.30am local time (7.30pm Sydney time). An hour later, they were on board the van that would carry them the 11 kilometres from their quarters in the Manned Spacecraft Operations Building to the launchpad. By 6.50am they were ready to enter the Command Module to begin their flight to the Moon. Armstrong was the first to be strapped into the spacecraft, followed by Collins and then Aldrin. By 7.52am, the Command Module hatch was sealed and the crew began their final preflight checks.

Go for the Moon

With perfect weather conditions, the Apollo 11 countdown was smooth and uneventful and the mighty Saturn 5 rocket lifted off at 9.32am local time (11.32pm Sydney time), only 724 milliseconds late! The launch was beamed live around the world to many countries, including Australia. At a time when satellite communications was still a relatively new technology, the ability to watch the launch live from half way around the world added an extra dimension of technological thrill to the excitement of the launch itself.

At exactly 10 minutes after liftoff, Apollo 11 reported that it was 'go for orbit' and the spacecraft, having shed its enormous first and second rocket stages, manoeuvred into a parking orbit around the Earth. The elegance and precision with which the first phase of the flight had been completed led someone in the Kennedy Launch Control to joke 'it must be the computer simulation tapes'! As the Apollo 11 crew made their first orbit of the Earth, NASA tracking stations around the globe, including Carnarvon in Western Australia and Honeysuckle Creek in the ACT, monitored the spacecraft's progress and kept in touch with the astronauts.

Halfway around the second orbit, the third stage engine was re-ignited, to boost Apollo 11 into its trans-lunar trajectory. Three hours and fifteen minutes after launch, the Command and Service Modules (CSM) separated from the Saturn 5 third stage, which housed the Lunar Module. The crew then turned the CSM and docked it with the Lunar Module, pulling the landing vehicle clear of the rocket stage. Once this manoeuvre was complete, the Apollo 11 space-craft jetted away from the rocket stage, which was then sent into a trajectory that would carry it away from the Moon-bound ship and into an orbit around the Sun.

Only after these difficult and potentially dangerous manoeuvres were completed, was the crew allowed to relax and remove their helmets, gloves

and pressure garments (the outer layer of their spacesuits). Seven hours after liftoff, the astronauts were finally able to eat their first meal in space: beef and potatoes, butterscotch pudding and four brownies, washed down with grape punch. Housekeeping chores, such as unpacking equipment, stowing other items, stellar observations for navigation purposes and medical checkups, occupied the astronauts' time for the next five hours until supper. Then, 13 hours after liftoff, Armstrong, Aldrin and Collins settled down for their first nine-hour sleep period. It was 1.04pm July 17, Sydney time.

Leaving Earth behind

Awakened 22 hours after launch, the crew prepared for their second 'day' in space. The main event of the day was to be a mid-course correction engine firing. Collins was responsible for taking a number of star sightings to check the orientation of the CSM prior to the course correction. Although he was able to observe the Earth clearly through his navigation telescope and sextant, he was initially unable to locate one star that he needed to complete his observations. Eventually, it was determined that the Lunar Module, attached to the nose of the CSM, was actually obscuring Collins' view of the star! The mid-course correction took place at 26 hours and 46 minutes after launch (2.18am July 18, Sydney time). This mid-course burn was required to slightly adjust Apollo 11's course. It lasted 3 seconds. By this time the spacecraft was over halfway to the Moon and its velocity was down to 5,507 km/h, having left Earth orbit with a speed of 38,916km/h.

Once the mid-course correction was complete, the crew had little to do until the next rest period except exercise, eat and enjoy the view. Mission Control in Houston continually asked the astronauts to describe their observations: could they see certain features? What was the weather like in different places across the US and in other countries? How did the oceans reflect sunlight? These apparently 'touristy' questions actually had a serious intent, aiding scientists on Earth as they attempted to gauge the extent of visibility and resolution from space, while they planned the earliest remote sensing satellites.

As the Apollo 11 crew's second day in space drew to a close, the astronauts turned on a colour television camera for their first live television show for the people of the Earth. Viewers were treated to a quick tour around the spacecraft, a view, out of one window, of the radio antennae, a demonstration of weightlessness from Armstrong and instruction in how to make a meal in space. Thirty-eight hours after launch, the crew settled down for their second 'night' in space.

Above: *The Apollo 11 crew: Neil Armstrong, Mike Collins and Buzz Aldrin.* ***Below:*** *The Saturn V rocket lifts off from the Kennedy Space Centre in Florida.*

The third day began with the good news that the next mid-course correction would not be necessary, as the spacecraft's trajectory was fine. After lunch, however, the programme became busy, as Armstrong and Aldrin prepared to crawl through the docking tunnel into the Lunar Module, to confirm that it had safely come through the launch. A ninety-minute live television broadcast transmitted this event to many countries, including Australia. Unfortunately, although the transmission was in colour, we in Australia could only see it in black and white, as colour television had not yet been introduced.

After the Lunar Module was pressurised with oxygen, Columbia's hatch was opened and Armstrong and Aldrin entered the Eagle. They showed their audience briefly around the tiny spacecraft which would make the descent to the Moon. Aldrin made a point of displaying the helmets that the astronauts would wear for their moonwalk, which had two extra visors in addition to the normal spacesuit helmet visor: one to protect from micrometeoroids, the other (coated with a thin film of gold) to protect the astronaut's eyes from the intense glare of the Sun. At 11.32 am July 19, Sydney time, the astronauts bedded down for their third 'night' in space.

It was during the third day of the mission that concern began to arise about the purpose of the Soviet Luna 15 mission, which had been launched towards the Moon on July 13. The probe went into lunar orbit on July 18, Sydney time, and it was feared that it represented a potential Soviet attempt to interfere with the Apollo landing in some way. There was particular concern that its radio frequencies might conflict with those of Apollo 11 and so cause a potentially catastrophic radio jamming. Astronaut Frank Borman, who had recently visited the USSR, was asked to seek assurances from the Soviet Academy of Sciences that there would be no radio conflict. Such assurances were quickly given in a telegram from Academician Keldysh, the President of the Academy.

A critical day

The fourth day of the mission was to be a critical one, ending with the Apollo spacecraft in lunar orbit. It began with the cancellation of another mid-course correction burn, because the flight was going so well that the spacecraft was within 0.6 metres/second of its planned velocity. Instead the crew listened to the news from Earth, which included a report that Pravda, the Soviet newspaper, had referred to Armstrong as 'the czar of the ship'! The astronauts reported back to Mission Control in Houston that 'the Earthshine is so bright you can read a book by it'. They were now far enough from the Earth that its glare, which had previously made star observations difficult, had reduced so that the stars could be easily seen against the black sky. They also began to comment on the spectacular appearance of the Moon, now filling about three quarters of the view through the hatch window. Said Armstrong: 'it's a view worth the

price of the trip'.

The lunar orbit insertion burn took place at 75 hours and 54 minutes after launch. The CSM was turned, so that the firing of its engine would brake the craft into lunar orbit. This was a critical manoeuvre, which required the engine to be fired for six minutes. If the burn failed, Apollo 11 would loop around the Moon and head back to the Earth; if it lasted too long the spacecraft would crash onto the lunar surface. The laws of celestial mechanics decreed that this burn had to take place while Apollo 11 was around the far side of the Moon, out of radio contact with Earth, thus increasing its hazard potential, and the world waited anxiously for confirmation that it all had gone to plan. Fortunately, the burn was a complete success and Apollo 11 swung into its intended lunar orbit.

Making ready

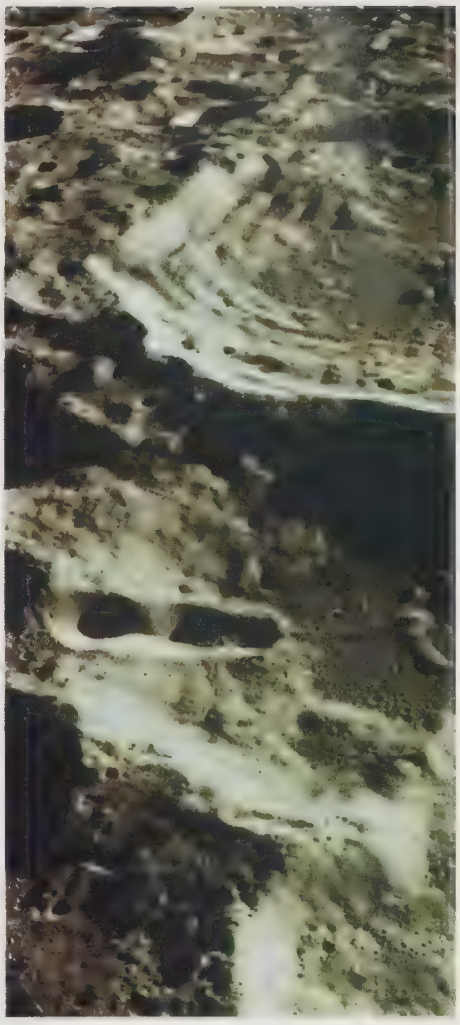
The crew studied the lunar surface, viewing their landing path for the descent to the Moon. As the astronauts made their second orbit they switched on the television camera and transmitted pictures of the lunar surface as they swept over it, about 160km up. On the third orbit, they again fired the CSM engine to circularise the orbital path. It was now 7.37am July 20, Sydney time, and Apollo 11 was travelling at 5,954km/h in an orbit of 100 x 120kms. Armstrong and Aldrin then entered the Lunar Module again to make a final check before the landing attempt the next 'day'. Everything was found to be in order and the astronauts returned to the Command Module, to eat their first meal in lunar orbit. It was now 11.32 am July 20, Sydney time. As Apollo 11 orbited the Moon, the mysterious Luna 15 changed its orbit, creating more speculation over whether or not it was preparing to land.

Around 9.15pm July 20, the crew were wakened from their sleep period. After breakfast, the astronauts began to don their pressure suits, in turn, while the Eagle was switched on and its systems checked out. Three hours later, the hatches between the two spacecraft were closed and final checks were carried out before they undocked. Armstrong and Aldrin strapped themselves into the harnesses at their respective stations in the Eagle (Armstrong on the left, Aldrin on the right), while Collins prepared to release the last of the docking latches. Finally, at 100 hours and 38 minutes after launch (3.10am July 21, Sydney time), the Command and Lunar Modules separated and the Eagle began its descent to the Moon.

As Eagle slipped away from Columbia, Armstrong reported that he was 'Going down US 1', using the nickname that the astronauts had given to the descent path to the landing site. One hour later Eagle fired its engines for insertion into its descent orbit. At 15,240 metres above the lunar surface, Armstrong made the final decision to commit to the landing and pressed the 'proceed' button on the tiny LM computer. Immediately the descent engine burst into life at the beginning of a 480km long arc down to the landing site at the south-western edge of the Sea of Tranquillity. As the Eagle made its decent to the Moon, the alarm light on its control panel flashed repeatedly due to overloading of the computer with more data than it could handle, but the situation was not serious.

At 153 metres above the landing site, Armstrong realised that the LM's course was taking the craft directly into a crater 'big enough to house the Houston Astrodome' and full of large boulders - a most unsuitable landing site (Eagle's course had actually caused it to come in a little over 3km short of its intended position). Immediately, Armstrong took control of the craft and guided the Lunar Module to a safer landing site. As he edged the Eagle towards touchdown, the tension began to mount, as the LM's small fuel reserves came close to empty.

Some 6.5km from the originally selected landing site, Armstrong found a place to touch down. With only 20 seconds of fuel left, the LM's engine was cut as soon as the landing probes signalled contact with the lunar surface. The Eagle settled onto the surface of the Moon and Armstrong was able to report 'Tranquillity Base here, the Eagle has landed'. Mission Control's relieved response, 'Roger, Tranquillity, we copy you on the ground. You've got a bunch of guys about to turn blue. We're breathing again. Thanks a lot.' referred more to the danger that had existed that the LM might crash if its fuel supply ran out, than it did out of excitement!



Above: *A desolate lunar landscape greeted the astronauts.* ***Below left:*** *The Eagle lunar module separates from the command module.* ***Below right:*** *Millions of people around the world watched humankind's first steps on another world.*

For the first time, human beings had landed on another world. Mission Control erupted in spontaneous applause, tears and cheering. Around the globe people were able to watch the event live, vicariously sharing the excitement of the historic landing. It was 102 hours and 45 minutes after launch, 6.18am July 21, Sydney time.

The adventure begins

Having landed on the Moon, the Lunar Module now became Tranquillity Base, although it was some time before Mission Control could figure out the exact landing site, due to the last minute overshoot. While Armstrong and Aldrin went through a rapid check of the spacecraft and a simulated countdown in readiness for an emergency takeoff (if required), Luna 15 was adding to the drama. It is now known that Luna 15 was an attempted sample recovery mission, intended to land on the Moon before Apollo 11

and return samples of lunar soil to Earth before the astronauts, thus stealing the thunder of the American mission, even if the USSR could not surpass it with its own crewed flight. This was not known in 1969. As Apollo 11 landed, Luna 15 moved into a low elliptical orbit, skimming only 16km above the Sea of Tranquillity at its closest approach.

Columbia was over the landing site during touchdown, in case an emergency liftoff was needed. As it passed out of range, the astronauts were committed to stay at least two hours on the Moon until the CSM was overhead again. As they began to take stock of their landing site and power down the LM, Armstrong and Aldrin commented upon the colour of the lunar surface seen up close, the size and shape of the rocks around them and the experience of moving in one-sixth gravity. They quickly decided that they were too excited to wait through the rest period that had been built into the mission profile, prior to the first moonwalk, and requested Mission Control's permission to move directly on to the preparations for their first extra-vehicular activity (EVA). When Mission Control concurred, Armstrong and Aldrin ate their first meal on the Moon, about 2 1/2 hours after touchdown and began to don their Moon suits. In addition to their basic spacesuits, their complete lunar kit included a second helmet with two visors, a pair of overgloves, and a pair of overboots, which fitted over the integrated boots of the pressure suit.

Aldrin was actually the closest to the LM hatch and it had originally been planned that he would be the first out of the Eagle and on to the lunar surface. However, as mission planning progressed, Armstrong insisted on his right as Commander of the mission to have the honour of being the first to step on to the Moon. His argument was backed up by elements of the US Government, who believed that, as a civilian, Armstrong was a less politically sensitive choice than Aldrin, who was a serving Air Force officer. Consequently, Armstrong had to climb awkwardly past Aldrin to reach the hatch and back out of it on his hands and knees.

The first step

At 12.51pm July 21, Sydney time, Armstrong crawled onto the 'porch' outside the hatch and gingerly felt with his feet for the first rungs of the ladder. As he went backwards down the ladder attached to a leg of the Lunar Module, he activated a small television camera, thus allowing the world to watch the actual moment that he stepped onto the Moon. At first, the picture appeared upside-down, then it righted itself (as NASA switched from its Goldstone tracking station to the signal from Honeysuckle Creek) and a ghostly figure could be seen coming down the ladder, while an inky-black sky and paper-white lunar surface appeared in the background.

Then, the momentous event arrived. 'I'm at the foot of the ladder', Armstrong said, 'The LM foot pads are only depressed in the surface about one or two inches ... I'm going to step off the LM now.' He lifted his left foot and, pushing it out a little, planted it firmly in the lunar dust. 'That's one small step for Man, one giant leap for Mankind' he said solemnly, as he stepped of the Eagle's foot pad, to stand firmly on the surface. It was 12.56pm July 21, Sydney time. (In his excitement, Armstrong actually made a slight slip in the statement he had intended: he meant to say 'That's one small step for a man'. As the actual words spoken on the Moon make no logical sense, Armstrong's intended words are what is usually reported!)

At last, Humanity had broken free of its planetary cradle and walked upon another world! That first step on to the Moon was history's most-witnessed foot print, with an audience of about 800 million people worldwide(including US Federal employees who had been granted special leave to watch the event!). Australia played a crucial role in ensuring that they were eyewitnesses to history. The signals from Apollo 11 came through the Honeysuckle Creek tracking station, near Canberra, which was handling communications with the Lunar Module, while Tidbinbilla maintained contact with the Command Module, in orbit above. The Parkes Radio Telescope was also receiving the LM signals. The initial broadcast of Armstrong's 'small step' was relayed via Honeysuckle creek, with Parkes taking over transmission for the rest of the broadcast 10 minutes later.

After his first step, Armstrong moved about gingerly on the surface, describing the lunar dust, and quickly picked up some contingency samples of lunar rock, in case he had to evacuate the surface in a hurry. As he collected them he described the Moon as having 'a stark beauty all its own ... like much of the high desert of the United States'. Attached to his chest was the still camera that was used to take many of the famous lunar photos. Because Armstrong carried the camera for most of the time, he does not appear in any of its images. Even when Aldrin had the camera, he was so busy photographing the LM that no one thought to have him snap shots of Armstrong! There is, in fact, only one photo in which Armstrong can be seen (apart from his reflected image in Aldrin's visor) and all the classic Apollo 11 images are of Aldrin! He is, however, readily seen in much of the television footage.

Eighteen minutes later, Aldrin left the Lunar Module and joined him on the surface. The two practised the difficult art of moonwalking for a few moments, becoming accustomed to moving in the one-sixth gravity, and then moved to the Eagle to unveil a plaque that had

been attached to its leg. Then Aldrin began to set up the solar wind experiment, which would collect subatomic particles of the solar wind. Armstrong busied himself fixing the television camera in position to view the scene of their activities.

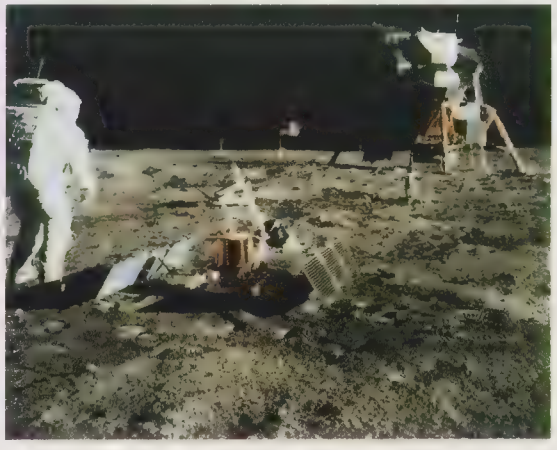
During that first history making period on the Moon, Mike Collins was actually out of contact with both the Eagle crew and Mission Control, on the far side of the Moon. Ironically, despite being in lunar orbit, he could not witness Armstrong's first step, or the unveiling of the plaque. He came back into contact with his colleagues on the surface just as they were about to set up the US flag. Originally, NASA had proposed that the astronauts set up the flag of the United Nations. However, the US Congress opposed this plan and instead an American flag stands stiffly, as if waving in an imaginary breeze, at the Apollo 11 site. The astronauts had great difficulty in making the flagpole stand upright and the 'wave' in the flag was actually the result of a telescopic pole not extending correctly! In addition to the flag, Armstrong and Aldrin also left a silicon disc containing microform goodwill messages from many of the world's leaders.

The raising of the flag was followed by a phone call from President Nixon in the White House (said to be the longest-distance phone call in history!). Nixon praised the astronauts for their achievement: 'Because of what you have done, the heavens have become part of Man's world, and as you talk to us from the Sea of tranquillity, it inspires us to double our efforts to bring peace and tranquillity to the Earth. For one priceless moment in the whole history of Man, all the people of this Earth are truly one.'

Moonwalking

The ceremonies completed, the astronauts then began the serious scientific business of their mission. Armstrong began to collect the 'bulk sample' - material from all across the landing area, while Aldrin inspected and photographed the LM and its effect on the lunar surface as it landed. The two men then deployed the Early Apollo Science Experiment Package, a solar-powered seismometer, for measuring moonquakes, and a laser reflector, enabling scientists on Earth to make precise measurements of the Moon's orbital movements. The seismometer was so sensitive that it was able to record the vibrations made by the astronaut's feet as they moved about the site, never more than 21m from the Eagle.

So successful was their EVA at this point (two hours on the lunar surface), that Mission Control decided to extend it for an additional 15 minutes beyond that originally planned. However, the astronauts now found that, even with the extra time, they had been so busy with ceremonies, photography and generally sightseeing that they were actually running behind their schedule. Their last major task, to collect a series of carefully documented and photographed lunar samples, became squeezed for time and was not completed with the detail that had been hoped for. Core samples were collected (with difficulty) and finally Mission Control instructed the astronauts to begin winding down their activities and prepare to return to the Lunar Module.



The astronauts spent a busy 135 minutes outside the lunar module. ***Above:*** *Aldrin descends the ladder to take his first step on the Moon.* ***Below:*** *The astronauts left behind a number of scientific experiments to give scientists a better understanding of our nearest celestial neighbour.*

The solar wind experiment was retrieved and the 21.75kg of moonrock samples stowed in the spacecraft.

After 2 hours and 37 minutes on the lunar surface (for Armstrong: Aldrin spent 2 hours 19 minutes), the two astronauts climbed back aboard the Eagle, at the conclusion of the first human excursion on another world. So rushed for time had they been at the end of their EVA that the two astronauts almost forgot a small ceremony that they had planned to honour their fallen comrades. Reminded of it by Armstrong, as they climbed into the LM, Aldrin tossed back onto the lunar surface a package containing the mission patch of the disastrous Apollo 1 mission, medallions that had belonged to Yuri Gagarin and Vladimir Komarov (Soyuz 1) and a small gold olive branch. An Apollo 11 patch was also left on the surface. It was 3.28pm July 21 Sydney time.

Once back in the Lunar Module, Armstrong and Aldrin prepared for their return to Columbia and home to Earth. Systems were again powered up and checked out and the Moonrock samples were sealed away in hermetic containers to prevent potential contamination from any organisms that might inhabit the lunar dust. In order to lighten the load for liftoff, to counterbalance the moonrock samples, and to prevent possible contamination, the astronauts' lunar equipment (life support system backpacks, helmets, overgloves etc.) was jettisoned, along with cameras, other equipment and rubbish. Then the hatch was finally sealed. At 114 hours and 30 minutes after liftoff (4.02pm Sydney time), Armstrong and Aldrin finally settled down to enjoy a meal and an eight hour rest period before they left the Moon.

About two hours before the Apollo 11 crew were due to leave the Moon, the saga of the mysterious Luna 15 came to an end. The space probe fired its retro rockets and appeared to be preparing to land. However, apparently having malfunctioned in some way, it crashed into the lunar surface, its mission a failure. The USSR quietly announced that the probe had completed its mission and, accepting defeat, joined in the world praise for the success for Apollo 11.

Goodbye to the Moon

The departure from the Moon was potentially as hazardous as the landing. If the ascent engine of the LM failed to fire, Armstrong and Aldrin would have been marooned with only a day's supply of oxygen and no hope of rescue. Fortunately, all went according to plan and at 3.56am July 22, Sydney

time, the Eagle soared away from the Moon's surface, towards its rendezvous with Columbia. Collins, who had been orbiting the Moon alone (recording a taped diary that later became the basis for his classic book on the Apollo 11 mission, *Carrying the Fire*) eagerly awaited the return of his colleagues. Like the descent to Tranquillity Base, some of the critical manoeuvring for the return rendezvous was performed behind the Moon, but each stage of the mission was successfully completed until the final moment of docking. As the two craft became latched together 'all hell broke loose', as Collins later remarked, and they began to gyrate wildly. This spinning was caused by the impact of the slightly misaimed LM with the CSM. Using the attitude control thrusters on both spacecraft, Armstrong and Collins quickly brought the spin under control and a dangerous situation was averted.

Before transferring to the Command Module, the two moonwalkers carefully vacuumed themselves, the sample boxes and the cameras and other equipment that they were bringing back, in order to prevent contamination. Only then did they re-enter the Columbia, where Armstrong quipped that it was 'nice to find a place to sit down!' An hour after docking, the Eagle, which had developed a number of worrying creaks and other noises, was jettisoned and the first crewed vehicle to touch down on another world was left in lunar orbit as a veritable museum of the first lunar landing. The crew then settled down to a meal, preflight checks before the insertion into trans-Earth trajectory and a good ten hours' sleep.

It was now July 23 and the Apollo 11 crew were ready to begin their homeward journey. At 5.37am July 23, Sydney time, the CSM engine was fired to manoeuvre the spacecraft out of lunar orbit and on a path back to the Earth. No further corrections would be needed after this burn, and the astronauts settled into a leisurely, restful routine as they coasted back to their home planet. There were virtually no flight activities planned for the return to Earth run, although the astronauts did take many images of the globe (images that, like those of Apollo 8 were important in giving impetus to the environmental movement) and broadcast some live television sessions back to Earth. Collins demonstrated how to shave in space, while Aldrin turned a food can into a gyroscope and showed viewers how to make sandwiches in microgravity. At 9.03am July 24, Sydney time, the Apollo 11 crew made their last broadcast from space, in which each of the three expressed their thoughts on the historic flight. All gave praise to the many thousands who had worked behind the scenes to make their mission a success.

Back home

The final stage of the flight began 1.22am, July 25, Sydney time. The Service Module, its purpose now fulfilled, was jettisoned. Only the Command Module, one tiny part of the massive Apollo Saturn 5 vehicle that had set out on the journey to the Moon, was coming home. It began to fall towards the Earth and re-entered at almost 39,000km/h, its blunt-end heat shield poised to take the searing heat generated by the return to the Earth's atmosphere. Finally, at 1.50am, July 25, the Command Module splashed down in the Pacific Ocean, some 1530km south west of Hawaii, and the epic voyage of Apollo 11 was complete. President Kennedy's bold promise of 1961 had been fulfilled, ahead of schedule, and the Space Race had been effectively won by the United States.

However, for the astronauts, the mission was not yet over. Quarantined for 21 days, in case they had returned carrying unknown lunar germs, they disembarked from the Columbia wearing fully-masked isolation suits and were quickly transferred to an isolation chamber that would be their home until quarantine was complete. President Nixon, who flew to congratulate them on the recovery ship, announced that it was the 'greatest week in the history of the world since the Creation' (a claim which drew howls of protest from Christian groups who cited the week of the Crucifixion as of greater importance) and soon the Apollo 11 crew would be hailed as heroes and feted around the world. The precious lunar rocks were transferred to the Lunar Receiving Laboratory at Houston, for distribution to scientists (see 'Pieces of another world', page 26) for analysis.

The dream of travelling to the Moon is as old as Humanity. Whatever political propaganda value lay behind its inception, the Apollo 11 mission took that dream and made it reality. For the very first time, Humanity became a truly spacefaring species, fulfilling rocketry pioneer KonstantinTziolkovski's vision that we could 'not remain in the cradle forever'. Whatever else may happen in the history of space exploration, whatever planets we may one day reach, or stellar systems we may one day explore, there can only be one 'first time' that Humanity sets foot on another world. Apollo 11 was the triumph of technology and the human spirit that became that first step. S&S

Kerrie Dougherty is Curator of Space Technology at Sydney's Powerhouse Museum, and co-author of the book, Space Australia.

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Pieces of another world

by Professor S. Ross Taylor

Twenty-five years ago, an Australian scientist was given the awesome task of analysing the first samples of rock from the Moon. Ross Taylor recalls those exciting days at the Lunar Receiving Laboratory . . .

It was July 20, 1969. At Mission Control at the NASA Manned Spacecraft Center (now the Johnson Space Center), Houston, Texas, the live television coverage of the first manned lunar landing was projected on a large screen. A group of scientists and engineers were looking, 'in real time' in the NASA jargon, at the grey powdery surface on which Neil Armstrong was walking. His feet sank in a little as though he was on a sandy beach from which the tide had receded.

I sat among the audience, seeking some clue from the picture and keenly aware that, if the astronauts returned safely from the harsh lunar environment, I would soon hold some of that sandy soil and those rocks in my hands. My task would be to discover their chemical composition, and so make my contribution to debates that had raged ever since Galileo had first turned his telescope on that alien landscape in 1610. What is the composition of the Moon? How old is it? How did it form? Perhaps we would soon know the answers to these ancient questions.

A spectrum of choices

My first involvement with the Moon ocurred in 1956 in Oxford, where I was lecturing in mineralogy and geochemistry. Harold Urey, the celebrated chemist and Nobel Laureate, was a visitor to that ancient university. His lectures on the solar system turned my interest toward cosmochemistry, the chemistry of the universe.

Urey was fascinated by the Moon, believing it to be a primitive object left over from the earliest period of solar system history. But, although the Moon might provide decisive evidence about the early history of the solar system, the prognosis in 1956 was that no samples from the moon would be available before the end of the century, then over 40 years distant. Much attention therefore was focused on meteorites, those random visitors from outer space. They carried a record of early events in the solar system, but the chemical evidence was difficult to decipher, and the origin of the bewildering variety of meteoritic types was only dimly perceived. One distinguished geochemist of the period pronounced the record to be unreadable.

Tektites - Fragments of the Moon?

In the 1950s our position resembled that of the princess who longed for a piece of the Moon. Were there other possibilities for testing lunar composition in this 'no touch' situation? Some people thought that the small, enigmatic glassy tektites, scattered over large areas of the surface of the Earth, were derived from molten rock splashed from the Moon by collisions with asteroids, comets or meteorites. Here were samples I could examine with the techniques that I had available.

I had worked in Oxford with Louis Ahrens whose book, *Spectrochemical Analysis* was the standard text on the analysis of rocks and minerals using the technique of emission spectroscopy; now he asked me to collaborate on a revised edition. When he moved to Cape Town, I followed him and set up yet another spectro-graphic laboratory (eventually I set up four). Almost the first samples I analysed were tektites. If they came from the Moon, they could be expected to have compositions distinct from terrestrial rocks. We pushed the analytical techniques to the limits, but the chemical composition of the tektites remained stubbornly terrestrial. They resembled the compositions of sandy sediments, formed by erosion and deposition on the surface of the Earth. It seemed unlikely to me that the surface of the Moon had duplicated these geological processes, for which both air and water are necessary. Nevertheless, many workers continued to believe that tektites came from the Moon and I became increasingly embroiled in this raging scientific controversy.

As the 1960s progressed, new information about the surface of the moon became available. In 1966 the unmanned Soviet Luna-10 orbiter carried a detector to record gamma-ray emission from radioactive elements on the lunar surface. This instrument provided the first estimates of the abundances of potassium, uranium and thorium from that remote location. These values suggested a surface composition rather like terrestrial basaltic lava. The soft-landing US Surveyor spacecraft reported back data from the smooth dark lunar maria (that make the features of the 'Man in the Moon') that were consistent with basalts, very different from tektites.

Professor Ross Taylor during the heady days of Apollo 11.

Preparation for lunar samples

As the Apollo series of missions progressed, with only a few setbacks, it began to look as though a lunar sample would actually be brought to the Earth. These would be the first extra-terrestrial samples to be deliberately introduced into the Earth's biosphere. NASA began to construct a Lunar Receiving Laboratory (LRL) where elaborate quarantine procedures were installed to avoid the horrendous scenarios of science fiction. But scientists and the public would want to know the make-up of the samples long before they had been declared biologically harmless, and allowed into conventional laboratories. How should the samples

be examined during this enforced quarantine period?

Perhaps only a handful of Moon rock or soil, hurriedly gathered by the astronauts facing some unforeseen crisis, might be available. What was needed was a fast, comprehensive method that would use only a trivial amount of material. Emission spectrographs were the only instruments to meet these criteria. They could determine the abundance of over 70 chemical elements in less than 10 milligrams of sample. The powdered samples were placed in a cup drilled in a carbon electrode. A 10amp arc was struck with another electrode, just as in a carbon arc lamp. The sample was melted and vapourised at 3,000°C and the resulting atomic spectra, characteristic of each element present, were recorded permanently on a photographic plate. The method was very sensitive; detection limits for many elements were about one part per million. However, the successful use of the method was widely recognized as an art, dependent on the care, understanding and 'trained intuition' of the analyst.

As the prospect of a lunar sample return became ever more likely, the debate over the terestrial versus lunar origin of tektites acquired a new urgency. A conference on the topic at the Corning Glass Works in New York State was scheduled for March, 1969, to allow final statements and predictions before the moment of truth expected in July. My invitation to this conference had some unexpected consequences. One of the mineralogists summoned from the US Geological Survey to the LRL in Houston to assist in the study of the lunar material was Robin Brett, originally from Adelaide. He learned of my attendance at the tektite conference through an exchange of Christmas cards. He invited me to visit the LRL after the tektite conference.

The meeting at Corning was inconclusive; the democratic but unscientific method of taking a vote revealed an equal division between supporters for and against a lunar origin. Then I went to Houston where I was pleased to be able to see the preliminary stages for receiving the first samples from the Moon.

The Lunar Receiving Laboratory

I spent a couple of weeks in Houston looking over the Lunar Receiving Laboratory. Despite intensive preparations, the facilities were slender enough. During the initial planning of the LRL, it had been assumed that a quick, rough, qualitative analysis would suffice. In my experience, this usually spelled trouble. The group of technicians manning the spectrograph, although keen, had no prior experience in the difficult art of analysing rocks. An attempt to simulate the sample return using meteorites as analogues led to dire rumours of difficulties.

Ross Taylor examining a photographic plate containing the spectra of a lunar sample at the Lunar Receiving Laboratory, Houston, July 1969. Working under strict quarantine conditions, the scientists worked day and night to analyse the first lunar samples, giving a waiting world its first solid information on the Moon's composition.

As I was preparing to return to Canberra, I was summoned to the office of Bill Hess, NASA scientific director at Houston. He invited me to stay and join the team being assembled to make the preliminary examination of the lunar samples, within the quarantine facility at the LRL. My task would be to use the spectrograph to carry out the first chemical analysis. I was surprised by the invitation. I had seen something of the intense competition to obtain lunar samples, and I had not been included in the departmental team assembled to work on the samples at Canberra.

> ' The Greeks had imagined the heavenly bodies to be perfect and composed of shining crystal. The reality was much less exotic. '

The task was daunting enough as I surveyed the resources of the laboratory. Anywhere from six months to two years would be a reasonable time to get the laboratory into working order. I would have less than six weeks. It was too late to bring in other equipment or to change the basic constraints imposed by decisions taken years earlier. Fortunately the spectrograph was nearly identical to the one that I had installed in Canberra. I knew its idiosyncrasies and could apply my techniques without major modifications.

Not all the problems were scientific. NASA security was impressive and as a foreign citizen, I needed a full security clearance and a new visa. Both appeared as if by magic, in great contrast to previous experiences with US immigration officials. There was an ever-lengthening list of requirements: medical checks, quarantine and safety procedures and so forth. To achieve this I had to track down officials whose sense of urgency was not equal to mine. (It was curious at the height of the mission to pass offices where people were sitting with their feet on the desk).

The Lunar Sample Preliminary Examination Team (or LSPET, in the fashionable acronyms of the period) comprised eleven 'in house' NASA scientists and fifteen scientists of assorted specialties from American universities and research organisations such as the US Geological Survey (the latter body, claiming that rocks were their prerogative, had lost a long battle with NASA to handle the samples). Each member had his own unique skill: geologists who were experts on volcanic rocks; mineralogists who had studied glasses produced at meteorite impact craters on Earth; chemists who had specialized in gases; biochemists who might detect signs of life in the lunar soil (and who endured much scepticism from their colleagues); physicists who had specialised in detecting low levels of radioactivity; a bacteriologist and a micropaleontologist; all made ready for material from another world. No lunar religion ever had a more devoted band of adherents.

Science to a deadline

I started to organise the spectrographic laboratory. The instrument had been installed so that the samples could be handled only inside the biological barrier of stainless steel and glass, using portholes fitted with rubber gloves. The light from the electric arc inside the cabinet passed through a quartz window into the spectrograph outside the biological barrier. Weighing and handling milligram amounts of powder was difficult due to the high static charge set up in the dry atmosphere. This

problem was to become much worse with the bone-dry lunar samples.

The first step was to prepare spectra for the 70 or so chemical elements detectable by the instrument and I raided the chemical laboratories for compounds. About 100,000 spectral lines are potentially detectable. Many lines overlap and the possibility of the erroneous identification of an element not present, or missing one that was present, continued to haunt me. The technique depended heavily on precise calibration with samples of known composition, hopefully close to those expected from the Moon. This was a guessing game and I scrambled together a likely set of meteorites and rocks, some rushed from Canberra and others by phone calls to colleagues.

In the days before the landing, it was possible to make a case for the existence of almost any chemical element on the lunar surface. Perhaps volcanic vents rich in sulphur or boron might be present; perhaps I was wrong and the surface had the composition of tektites; perhaps the Moon was covered with cometary or meteoritic debris. What about the effects of the landing rockets on the samples? We obtained an analysis of the rocket exhaust cone. Its main constituent was niobium. The seals on the lunar sample box, designed to contain the lunar samples under vacuum during transit to the Earth were made of the soft element, indium (in the event, the seals, coated with lunar dust, failed to hold a vacuum). Both these elements might contaminate the sample. The scientific community would be outraged if I reported that these rare elements were major components of the Moon.

The preparations continued as I tried to cover all possibilities. Many small but essential items were rushed from Canberra. Only one camera had been bought for the spectrograph. What if it was dropped and damaged at the height of the mission? A spare was obtained at the last minute. The scenario became like a battle and, like one, had a tendency for the unexpected to arise. I recalled Wellington's comment on the morning of Waterloo, as he watched the French forming for the attack. 'Plans?' he replied to one of his anxious staff, 'I have no plans. I shall be guided by circumstances'.

The first Apollo 11 lunar sample is unloaded at the Lunar Receiving Laboratory. The box had arrived only minutes earlier from the splashdown site in the Pacific.

The first samples

The lunar landing occurred on July 20 (July 21 in Australia). No clues to the composition of the surface appeared on the television screen. Back in the laboratory, we made our final preparations. On July 26, the lunar sample box arrived in Houston and was opened. The ancient Greeks had imagined the heavenly bodies to be perfect and composed of shining crystal, the quintessence or fifth element of the ancient cosmologists at Alexandria. The reality was less exotic. The dust-covered rocks looked like charcoal briquettes used for barbeques. Once the dust was brushed off, the rocks were beautifully fresh due to the absence of water and air on the Moon.

> "The report stated . . . it is clear that some of the Apollo 11 rocks may date back to times earlier than the oldest rock found on Earth."

Two days later, at 11.45am on Monday, July 28, the first sample came into the laboratory. I had completed the final calibrations, about an hour earlier. By 12.28pm, the first lunar sample, a soil, was prepared and loaded into the cup-shaped electrode. The excitement of the moment, and the tendency of the lunar dust to adhere to everything, together with the difficulty of working in a glove box, made this routine operation difficult. The sample was vapourised in the direct current arc. It gave off a red colour, followed a little later by a white fringe to the flame that suggested titanium.

The photographic plate, recording the spectra was developed, and I began to examine the host of spectral lines from the first sample from the Moon. In the midst of this interpretation, the clamour of a 'spill alarm' (a possible break in the quarantine) sounded through the laboratory. We put on gas masks and continued to inspect the plate with its forest of lines. The spectra were complex, for the sample contained major amounts of iron, titanium and chromium, all elements with hosts of spectral lines. What did the sample look like? It certainly wasn't a tektite. It was closest to a terrestrial basaltic lava, but had about 10 times as much titanium, a 'refractory' element, and about five times less sodium, a 'volatile' element. These were significant differences that turned out to be characteristic of the Moon, and were to provide important clues to its origin.

Some analytical dilemmas

The analysis for sodium was particularly difficult. The high concentrations of chromium interfered with the sodium line and gave spuriously high, but credible values for sodium. We barely avoided a potential disaster, recognizing the problem and correcting it just before the results were rushed off to a waiting press conference. By now it was 4.00pm, only a few hours after we had received the sample. The results were spread around the world by the news media.

Having established the major constituents of the sample, I turned to determining the trace elements. These had the potential to add further vital information. Another spill alarm closed the laboratory at 11.00pm. I got back in at 7.00am and discovered yet another major problem. The high and unexpected concentration of chromium required a complete recalibration for all our trace element standards. This was a typical analytical problem that would take, in normal

times, a couple of weeks to pin down and solve. It was done by 11.00pm that night, at which stage I realised that I had forgotten about supper. There had been another alarm about 2.30pm which put us all back into gas masks for an hour or so. These alarms, with their attendent searches for leaks in the cabinets, were to bedevil us throughout the mission. Next day, July 31, I was able to report the trace element data and provide information on the total composition of the sample.

In the next three weeks, we carried out full analyses for 23 assorted rocks and soils. Every afternoon, at 4.00pm I reported on and discussed the data with the Lunar Sample and Analysis Planning Team (LSAPT). This group comprised about eight of the leading scientists of the period and I was subjected to extensive grilling about the results: 'Surely the sodium values can't be that low; are you sure about the lead concentrations?' and so on. The task soon became an obsession and the laboratory, secure behind its guards (armed!) and quarantine barriers, with its ultraviolet irradiated tunnels, through which we passed after changing clothes and taking showers, became for us the real world. My day usually extended from 7.00am to somewhere between 2.00 and 3.00am the next morning

The glare of publicity

Although the laboratory was isolated, we were not remote: the news media beseiged us for information, and I developed a new respect for the incisive and competent science reporters of the major world press. There were the daily interrogations from LSAPT. One day I received 30 minutes notice to explain the chemical results to the senior NASA administrators. Nothing in my previous scientific training had prepared me for the speed and urgency of the task. I found that science could be done quickly.

On August 20, we finished the analytical work, and wrote, in four days, the account of the study. This was published in *Science* on September 19. It is an interesting commentary on the nature of scientific work and of the power of data over speculation, that so many solid facts about the Moon were presented in this paper. The strength of science lies in facts; this advantage is not shared by most other fields of human activity. This first set of lunar data, although from a few limited samples, swept away generations of fruitless speculation, and, in turn, produced a new set of questions.

My task had been to establish the unique chemistry; others had described the rocks and minerals, and had established that the rock samples from Mare Tranquillitatis the 'Sea of Tranquillity', were from volcanic lava flows. Other workers had searched for signs of life, and water, without success; the Moon was 'bone-dry'. One conclusive result was that the theory that

For the first three Apollo missions, the lunar samples were kept under strict quarantine conditions inside airtight compartments to avoid the (unlikely) possibility of contamination by extraterrestrial organisms.

tektites came from the Moon died from a massive overdose of lunar data. But I reflected that my interest in tektites, which I had long regarded as terrestrial in origin, had ironically been a factor in leading me to Houston.

We also calculated an age for the lunar samples, based on my measurements of the abundance of potassium, and that of its radioactive decay product, argon, measured by the gas experts. We showed that the samples were of great antiquity, between three and four billion years old. We received some criticism for this from LSAPT, who considered this task beyond our brief, but the significance of the result overrode the tidy organizational scheme decided in advance of the mission. As we stated in the report in *Science:* 'Perhaps the most exciting and profound observation made in the preliminary examination is the great age of the igneous rocks from this lunar region - it is clear that the crystallisation of some Apollo 11 rocks may date back to times earlier than the oldest rock found on Earth'.

The moment of truth

I flew back to Canberra in a daze of exhaustion. Now the lunar samples were distributed widely to the Lunar Principal Investigators. My analyses would be checked in minute detail by analysts who had been preparing for several years, who had more precise equipment, and who could analyse the samples on the open bench, rather than through biological barriers. There was an agreed embargo on publication until the first lunar science conference, scheduled for January, 1970. After a couple of months at home, spent moving into the house my wife had completed in my absence, and getting ready for the next mission, I returned to Houston in November to repeat the exercise for the Apollo 12 lunar landing. The samples were broadly similar to those from Apollo 11, we knew what problems to expect, but there were still a few surprises. We finished the task just in time to write another paper for *Science* over Christmas.

Early in January, the Principal Investigators assembled in Houston with their data on the Apollo 11 samples; it was to fill 3,000 pages. The chemical results agreed in detail with my first analyses. Yet I was too exhausted to feel much emotion. The morale of the LSPET had been high - now we met like the survivors of a well-fought campaign. The whole affair had been, as Wellington had commented after Waterloo, 'the nearest run thing you ever saw in your life'. S&S

Ross Taylor is Professor of Geochemistry at the Australian National University. He is a world authority on planetary origins and served for many years as the president of the International Meteoritical Society.

For a complete account of the origin and evolution of the Moon, see Ross Taylor's article, 'Understanding the Moon', in our November 1992 issue.

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THE SOUTHERN SKIES by Martin George

The spring sky is full of bright stars and beautiful constellations - in this issue, Martin George guides us through the sky to two fascinating constellations.

As the spring sky darkens, the brilliant constellations of Scorpius and Sagittarius are very high in the sky, and we see the Milky Way towards the north and west. Following the plane of our galaxy to the south west, we see the Southern Cross with the pointers above it.

Turning to face the opposite direction, we can watch the Great Square of Pegasus making its appearance in the north east. Very low in the north, we see the star Deneb as it makes a brief appearance over our horizon. Deneb is the 19th brightest star in the sky, and gazing above it and to its left, we see the most well-known part of the constellation of Cygnus, the Swan - the configuration of stars known as the Northern Cross. The star at the upper left of the Cross is Beta Cygni, or Alberio. This is a fascinating double star; if you haven't seen it before, it's really worth a look! Any small telescope will show its two stars - they are of magnitudes 3 and 5 and are separated by an easy 34 arcseconds.

After that little diversion, let's head higher in the sky. About 20 degrees above and slightly to the right of Alberio, in the constellation of Aquila, The Eagle, lies Altair - one of the brightest stars in the sky. Last year at this time, I recall that we used Altair as a guide to finding the little constellation of Sagitta, The Arrow, which lies just to its north. In this issue, let's take a look at two more small constellations - Delphinus and Equuleus - that lie just to Altair's east.

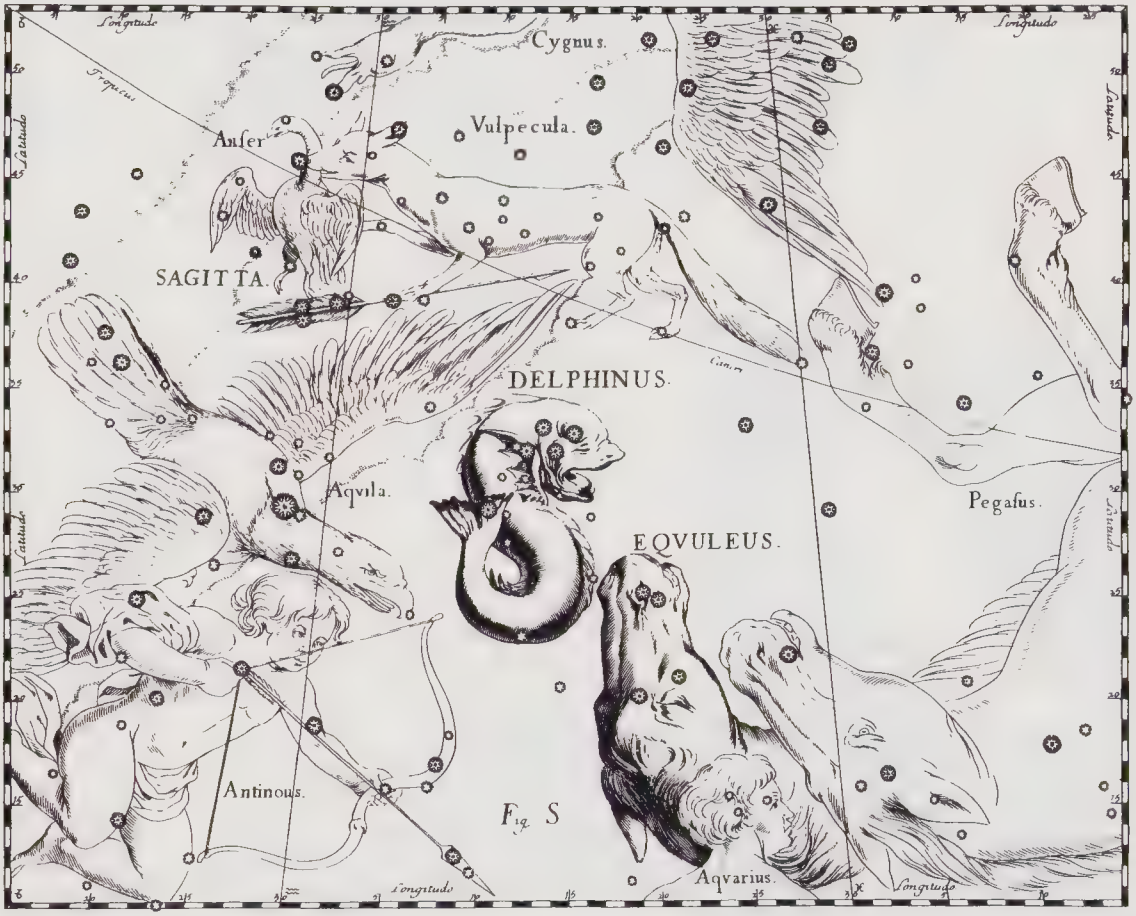
Delphinus and Equuleus

The ancient constellations of The Dolphin and The Little Horse lie between Aquila and the large constellation of Pegasus. Delphinus is by far the more prominent of the two, as it contains a delightful little group of several third and fourth magnitude stars just off the main stream of the Milky Way which I find very attractive to view with binoculars. Equuleus, to its east, is much fainter. It is the second smallest constellation in the sky, covering only about three square degrees more than Crux Australis. As with many of the constellations, I am afraid I find very little resemblance in these star groups to the creatures after which they were named! Equuleus is also known as The Foal, and it is thought that the two were originally one constellation (The Dolphin) before the Greek astronomer Hipparchus split off Equuleus in the second century BC.

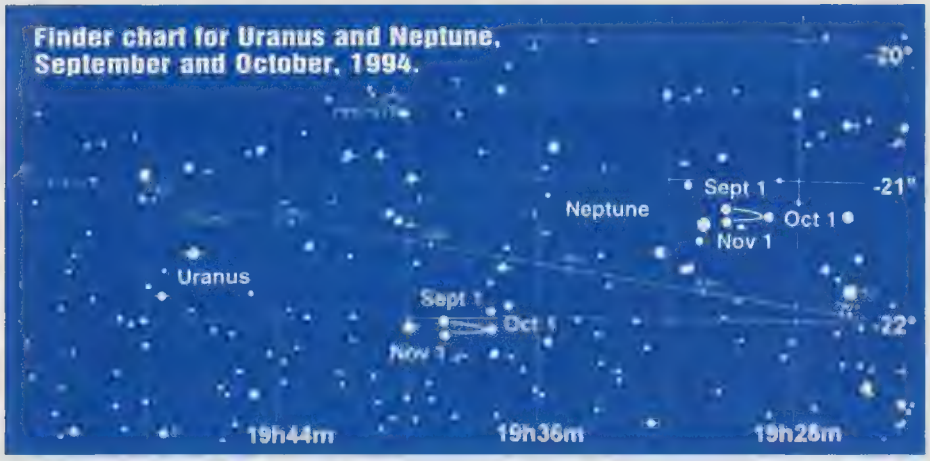
There is an interesting story associated with the names of the two brightest stars in Delphinus. Alpha and Beta Delphini are named Sualocin and Rotanev, respectively. At first sight these may appear to be Arabic names, but they first appeared in the Palermo Catalogue in 1814, and are named after Nicolaus Venator, who was an assistant to Giuseppe Piazzi, the discoverer of the minor planet Ceres.

There are a few objects for the telescope within these two groups of stars, probably the best of which is the double star **Gamma Delphini** - the one at the bottom right of the main group. Gamma's two stars are of magnitudes 4.5 and 5.5 and are easily split using a small telescope, being separated by 10 arcseconds.

Two globular clusters in Delphinus are of interest. The brighter one is **NGC 6934**, which is of the ninth magnitude and can be found in a small telescope, although larger apertures are needed to start resolving it. The other,



***Right:** Delphinus and Equuleus are clearly shown in the star chart entitled* Uranographia Totum Coelum Stellatum *by Johannes Hevelius (1690). The chart appears reversed with respect to east and west because the stars are represented as they would appear on a celestial globe viewed from the outside!*



This chart, which shows the motions of the distant planets Uranus and Neptune in Sagittarius during this period, is adapted from Uranometria 2000 Volume II (Willmann-Bell Inc., 1988). It is printed with north to the top. Start by locating the star 56 Sagittarii, one of the brightest on the chart, which is shown on Wil Tirion's map on the centre pages as a fifth-magnitude star 7 mm above the "C" of CAPRICORNUS.

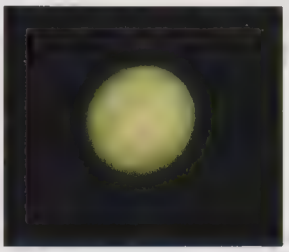
NGC 7006, is rather fainter at eleventh magnitude, but this is hardly surprising: it is one of the most remote of the globular clusters. Sky Catalogue 2000.0 lists its distance as 34.7 kiloparsecs (113,000 light years), while Burnham's Celestial Handbook quotes an estimate of 185,000 light years! When searching for NGC 7006, it may help to note that it has almost exactly the same declination as Gamma Delphini, and is about five degrees to its east (i.e. to the right).

Unfortunately, the tiny constellation of Equuleus has little of interest to the telescopic observer, but the star **1 Equulei (Epsilon)** is an interesting double. Its sixth- and seventh-magnitude stars are separated by 11 arcseconds. It is found not far from the south-western (upper left) corner of the constellation.

Right: *This chart, which includes stars to about magnitude 5, shows the region of the sky including Delphinus and Equuleus, representing the view obtained from the Southern Hemisphere when the two constellations are to the north. They are easily found by first locating the bright star Altair in Aquila. The objects mentioned in the text are labelled.*

The Planets

Having been visible in the western evening sky for several months, brilliant **Venus** still dominates the view, outshining the giant planet Jupiter which is seen above Venus and to its right. At the beginning of September, Venus passes less than one degree south of the bright star Spica in Virgo (their closest approach occurs around 21h UT on August 31). Venus is a spectacular object to watch through the telescope during September and October, as it approaches us and its phase diminishes from 44% in early September to a very slender crescent by late October when it finally becomes lost in the evening twilight.



Jupiter with its new black spots. Photo by Laurie Purcell.

Jupiter, in the constellation of Libra, is another fine subject for the telescope; even though it is several months past opposition, the planet's disc and some atmospheric detail can be seen easily, as can its four brightest moons. At the time of writing, the effects of the collision of Comet Shoemaker-Levy 9 with Jupiter during July are still visible, with the impact sites having largely merged together to form a new 'band' in Jupiter's southern hemisphere.

Lower in the western evening sky is tiny **Mercury**, which on the evening of September 21 passes less than eight arcminutes south of Spica, making it easy to identify. Mercury reaches its greatest elongation from the Sun on September 26, and then starts to retreat once again, at the same time becoming more interesting telescopically.

To the east, in Aquarius, is **Saturn**, which reached opposition on September 1 and is visible all night. Saturn is a splendid sight through the telescope, and regular observers will have no doubt noticed the changing tilt of the rings. Currently, they appear inclined only 7 degrees to our line of sight. In a way, this is disappointing for those seeing the planet for the first time, but for a period next year the rings will not be visible at all! Several of Saturn's moons are within the range of amateur telescopes; Titan,

Coordinates for this issue's objects of interest

Object	RA h	RA m	Dec. °	Dec. ′
Beta Cygni	19	30.7	+27	58
Gamma Del	20	46.7	+16	07
NGC 7006	21	05.5	+16	11
NGC 6934	20	34.2	+7	24
Epsilon Equ	20	59.1	+4	18

Data obtained from *Sky Catalogue 2000.0* (Hirshfeld and Sinnott, ed., Cambridge Uni. Press and Sky Publishing Corp., Cambridge, 1985).

the largest, can be seen in quite a small instrument, while larger ones will show Tethys, Rhea and Dione.

It has been quite some time since we have had a good view of red **Mars**, but unfortunately we still have quite a wait ahead of us. Mars is currently a morning object, moving eastward among the stars of Gemini and passing into Cancer in late September. Through the telescope Mars is a disappointing sight, with a disc only about 6 arcseconds across. Mars' next opposition occurs on February 12 next year.

The outermost giants - **Uranus** and **Neptune** - reached opposition during July. They can both be seen against the backdrop of the stars of Sagittarius, and their paths over the next few months are shown on the chart (previous page), which is adapted from *Uranometria 2000 Volume II* (Willmann-Bell Inc., 1988). Uranus is just brighter than magnitude 6; readers living well away from the city lights may like to see if they can spot it without optical aid. Through the telescope, its 4-arcsecond disc can be seen using high magnification. At eighth magnitude, Neptune is much fainter, requiring a telescope to see. Its tiny disc appears almost starlike. S&S

Martin George is Director of the Launceston Planetarium and President of the Astronomical Society of Tasmania. He appears regularly on Tasmanian television and radio to cover special astronomical events.

MOON PHASES

Last Quarter
Aug 29, 4.41pm
Sept 28, 10.23am
Oct 28, 2.44am

New Moon
Sept 6, 4.33am
Oct 5, 1.55pm
Nov 3, 9.35pm

First Quarter
Sept 12, 9.34pm
Oct 12, 5.17am
Nov 10, 4.14pm

Full Moon
Sept 20, 6.01am
Oct 19, 10.18pm
Nov 18, 4.57pm

Times in Australian Eastern Standard Time

Explanation of Terms

This table gives basic data on the position and appearance of the Sun and major planets. The first two columns are self-explanatory. The third and fourth columns, RA and Dec., are the right ascension and declination coordinates for that date - these are much like longitude and latitude on Earth. The fifth column gives the object's angular diameter in minutes (′) and seconds (″) of arc; as a guide, the full Moon is 30 arcminutes across. The sixth column indicates phase, or the degree to which the object shows a 'crescent' - 100% means the planet shows a complete disc; a lesser number indicates the disc does not appear fully illuminated from Earth. The second-last column (Elongation) gives the angular separation (east or west) from the Sun in degrees; the further it is, the better it is for viewing. The final column gives the apparent magnitude or brightness; negative numbers are brighter than positive ones, eg. -1.0 is brighter than +1.0, +1.0 is brighter than +4.0. Around +5.0 is the faintest the unaided eye can see under a dark sky.

Celestial co-ordinates for the Sun and major planets for September and October, 1994

See bottom left for explanation of terms.

Object	Date	R.A. h m	Dec. ° ′	Diam. ′ ″	Phase %	Elong. °	Mag.
Sun	Sep 1	10 40.2	+8 25	31 42.3	-	-	-
	16	11 34.2	+2 47	31 49.6	-	-	-
	Oct 1	12 28.1	-3 2	31 57.5	-	-	-
	16	13 23.1	-8 45	32 5.9	-	-	-
	31	14 20.2	-13 59	32 13.8	-	-	-
Mercury	Sep 1	11 42.3	+2 28	- 5.2	88	17E	-0.4
	16	13 0.6	-8 3	- 5.9	74	24E	-0.0
	Oct 1	13 59.2	-15 34	- 7.4	51	26E	+0.2
	16	14 1.5	-15 14	- 9.9	8	11E	+2.5
	31	13 19.9	-6 39	- 8.1	30	17W	+0.3
Venus	Sep 1	13 35.5	-11 55	- 26.6	45	46E	-4.4
	16	14 10.9	-17 56	- 32.6	35	44E	-4.5
	Oct 1	14 44.0	-22 17	- 41.2	24	38E	-4.6
	16	14 53.3	-23 55	- 52.5	10	26E	-4.5
	31	14 31.0	-21 8	- 61.3	1	8E	-4.1
Mars	Sep 1	6 43.0	+23 30	- 5.3	91	59W	+1.2
	16	7 23.3	+22 44	- 5.6	90	64W	+1.1
	Oct 1	8 1.1	+21 29	- 5.9	90	70W	+1.0
	16	8 36.1	+19 53	- 6.4	89	76W	+0.9
	31	9 7.7	+18 7	- 6.9	89	83W	+0.7
Jupiter	Sep 1	14 31.1	-13 53	- 33.8	99	61E	-1.9
	16	14 40.8	-14 41	- 32.8	99	49E	-1.8
	Oct 1	14 51.8	-15 33	- 32.0	100	37E	-1.8
	16	15 3.8	-16 27	- 31.4	100	26E	-1.7
	31	15 16.7	-17 20	- 31.0	100	14E	-1.7
Saturn	Sep 1	22 45.9	-9 59	- 19.0	100	178W	+0.5
	16	22 41.7	-10 25	- 18.9	100	165E	+0.5
	Oct 1	22 37.9	-10 47	- 18.7	100	149E	+0.6
	16	22 35.0	-11 2	- 18.4	100	134E	+0.7
	31	22 33.3	-11 10	- 18.0	100	118E	+0.7
Uranus	Sep 1	19 39.0	-22 1	- 3.8	100	134E	+5.7
	16	19 37.8	-22 4	- 3.7	100	120E	+5.7
	Oct 1	19 37.4	-22 5	- 3.7	100	105E	+5.7
	16	19 37.7	-22 4	- 3.6	100	90E	+5.7
	31	19 38.9	-22 1	- 3.6	100	75E	+5.8
Neptune	Sep 1	19 30.0	-21 13	- 2.3	100	132E	+7.9
	16	19 29.2	-21 15	- 2.2	100	118E	+7.9
	Oct 1	19 28.9	-21 16	- 2.2	100	103E	+7.9
	16	19 29.2	-21 16	- 2.2	100	88E	+7.9
	31	19 29.9	-21 15	- 2.2	100	73E	+7.9
Pluto	Sep 1	15 45.8	-5 48	- 0.1	100	78E	+13.8
	16	15 46.8	-5 59	- 0.1	100	64E	+13.8
	Oct 1	15 48.2	-6 11	- 0.1	100	50E	+13.8
	16	15 49.9	-6 22	- 0.1	100	36E	+13.8
	31	15 52.0	-6 33	- 0.1	100	24E	+13.8

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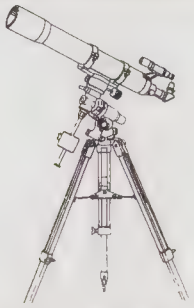
"..... the Bintel 102 represents excellent value.. It provides bright, 'contrasty' views..." Sky & Space reviewer, October issue.



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The STELLAR SPHERE

Use this night-sky star map in conjunction with 'The Southern Skies' article on pages 30-32.

This star chart has been drawn specially for SKY & SPACE by world-renowned celestial cartographer, Wil Tirion. He is author and co-author of many star atlases and books, including *Sky Atlas 2000.0*, *Uranometria 2000.0* and the *Cambridge Star Atlas 2000.0*. We are proud to be associated with his world-class work.

Sept 21, 1994
7.00pm

This is a view of the sky looking to the east, in the evening of September 21. The tiny planet Mercury, appears very close to the star Spica, the brightest star in the constellation Virgo. Mercury reaches greatest elongation (highest point above the Sun) on September 26. Higher in the sky are Venus and Jupiter. Venus shows a steadily decreasing crescent shape, whilst around Jupiter can be seen several moons. See The Southern Skies on pages 30-32 for more details.

Sept 30, 1994
5.00am

Mars is visible in the morning sky, moving eastwards night by night through the stars of Gemini and passing into Cancer in late September. Through the telescope, Mars is a little disappointing, with only a very small disc. The best time for viewing Mars will be in February next year. For more details see 'The Southern Skies' on pages 30-32.

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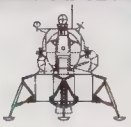

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The fascinating story of the 'Ghosts of the Solar System' is vividly told in this 30-minute program, produced by York Films of London in conjunction with the BBC. Utilising beautiful computer graphics and actual images, **Comet** tells the complete story of comets, from ancient myths to modern spaceprobes. The recent collision of a comet with the planet Jupiter, makes **Comet** an indispensable guide to these mysterious visitors to our Solar System. Approx. 30 min. $25.95 + P&H.

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Once in a lifetime . . .

In this modern age, it's not often that we get the chance to witness a totally new scientific phenomenon. The collision between fragments of Comet Shoemaker-Levy 9 and the giant planet Jupiter, is an event which has captured the public's attention and imagination like no other since the Voyager probes made their fly-bys of the outer planets. And whilst collisions between comets and planets have been predicted for many years, it came as a great surprise last year to find that we were about to see a comet hit the biggest planet of them all!

It also is fortuitous that the event has occurred when modern astronomy has reached a level of technical sophistication which is more than sufficient to capitalise on the opportunity. New electronic detectors which can detect infrared wavelengths, spaceborne telescopes with remarkable resolving powers, and computers able to rapidly process the mountains of data generated, have all contributed to make this one of the most observed astronomical events since the telescope was invented.

Perhaps the only disappointing note is that the Galileo spacecraft, with a launch that was put back by several years, was not actually in orbit around Jupiter at the time of the impacts: it is still 17 months away from arrival. Still, its position in space gave it the most favourable view of some of the action, and no doubt Galileo will contribute heavily to the scientific investigations as its data is slowly transmitted back to Earth.

Of course, we'll be covering all the latest developments in the ongoing story of Comet Shoemaker-Levy 9 in the pages of SKY & SPACE Magazine. You can be sure there will be many unexpected and fascinating findings from astronomers' investigations into this once-in-a-lifetime event.

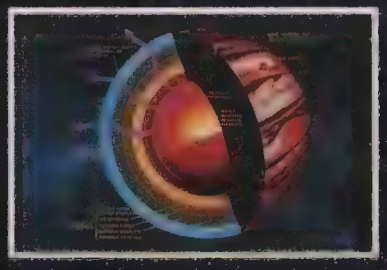
J. Nally, Editor, SKY & SPACE Magazine.

Jupiter: King of the Planets

Named after the supreme god in Roman mythology, Jupiter is in a class of its own. The largest of the planets (if hollow, it could hold over 1,300 Earths), Jupiter's mass is nearly three times that of all the other planets combined.

Jupiter emits 67% more heat than it absorbs from the Sun. This heat is thought to have accumulated during the planet's formation several billion years ago. Some scientists even classify Jupiter as a member of a hypothetical family of stars known as 'brown dwarfs', which are objects too hot to be considered planets but too cool to be classified as real stars.

Jupiter guards its secrets well, allowing us to see only about 80 kilometres beneath its upper atmosphere. Its outer atmosphere displays alternating patterns of belts and zones, visible through even small telescopes. The Great Red Spot is a raging storm, about three times the size of the Earth; first observed in 1664, it is the longest-lived cyclone known! Wind speeds in Jupiter's atmosphere reach around 800 km/h, and temperatures range from -130°C at the cloud tops to about 24,000°C at the centre of the planet. Jupiter has 16 moons and a thin ring system.

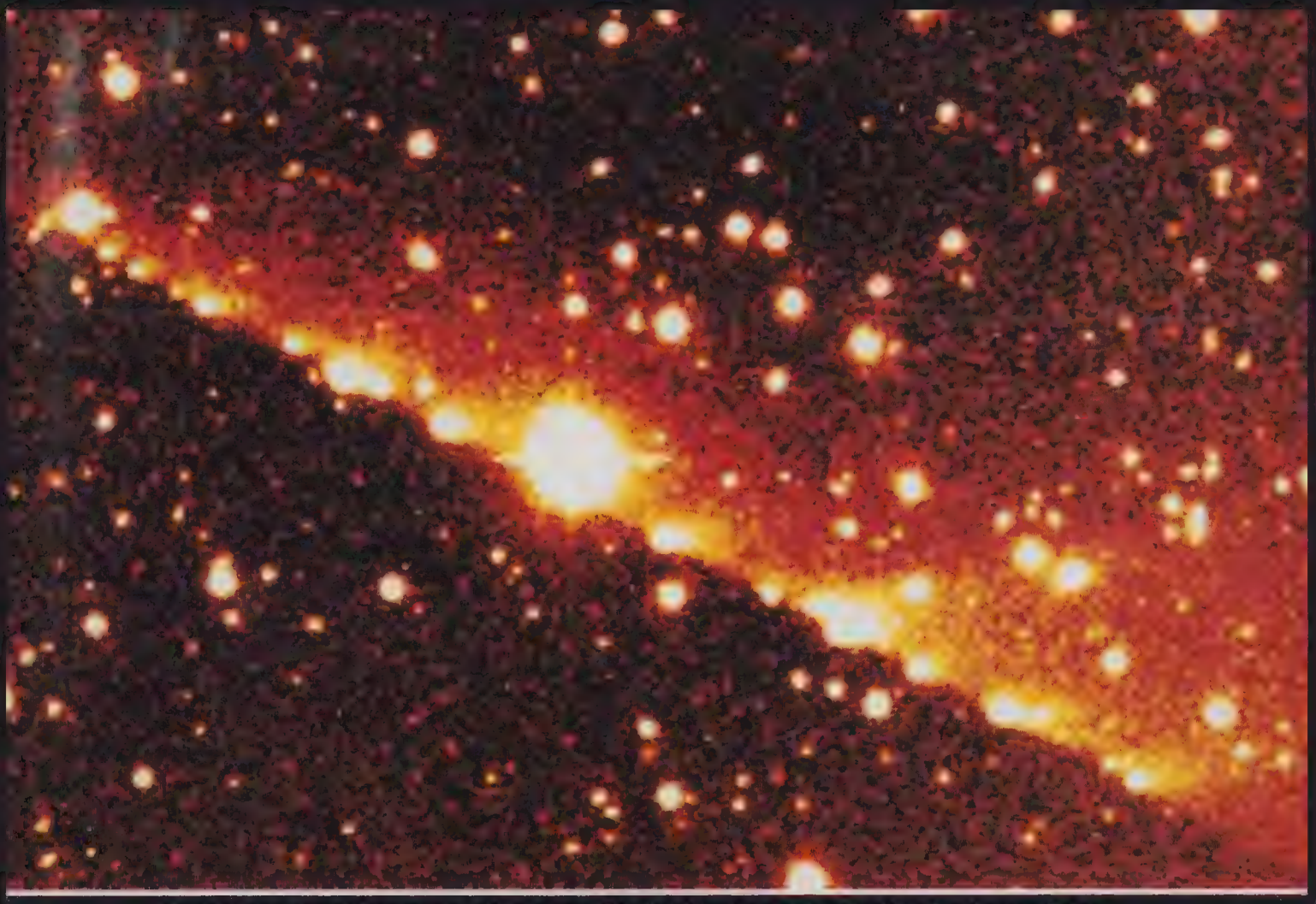


What is a comet?

Comets are the most mysterious bodies in the solar system. Whilst their orbital characteristics have been understood for centuries, little was known of their composition until a flotilla of spacecraft rendezvoused with Halley's Comet in 1985/86. In particular, the Giotto probe approached Halley to within 300 kilometres, providing our first close-up look at a cometary nucleus. Giotto found the icy body to be covered in a dark 'soot' of organic chemicals, lending credence to the idea that comets have played an important role in the development of life on Earth, through provision of both chemicals and water.

The nucleus of a typical comet is several kilometres wide and composed of ices and other volatile chemicals. Upon nearing the Sun, the ices evaporate, forming the coma, or 'head' of the comet. The solar wind then pushes the material outwards, forming one or more long tails. Large comets can have tails extending over tens of millions of kilometres.

Comets are believed to come from a halo of billions of comets surrounding our solar system, way out beyond the realm of the planets.



Twenty-one comet fragments, all in a row. The brightest point is actually a background star.

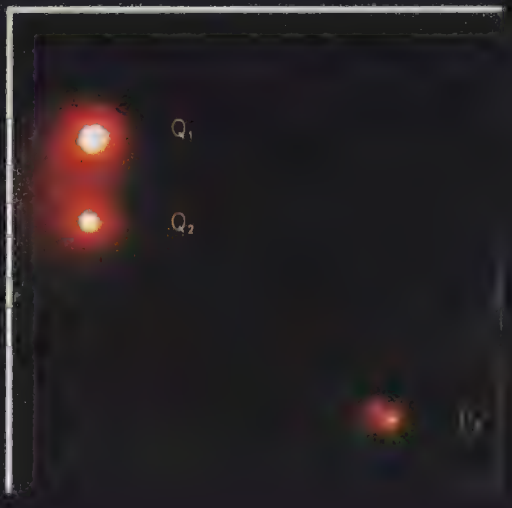
A very curious comet . . .

Between July 17 and 22, over 20 fragments of Comet Shoemaker-Levy 9 collided with Jupiter, hitting the atmosphere at speeds of over 200,000 km/h.

The unusual comet was discovered by Carolyn and Gene Shoemaker and David Levy on March 24, 1993, using telescopes of the Palomar Observatory in California - subsequent calculations showed that the comet was on a collision course with Jupiter. While such collisions with Jupiter are thought to occur as often as once each century, this was the first time such an impact had been predicted beforehand.

Originally, the nucleus of the comet was probably about 10 kilometres in size, but following a close approach to Jupiter in July 1992 it split into over 20 fragments. Individual pieces ranged in estimated size from as large as one to two kilometres in diameter, down to particles the size of dust grains.

The fragments spread out along slightly different orbits around Jupiter, appearing in photos like a 'string of pearls'. Astronomers were able to determine the impact points and times to high accuracy. Unfortunately, all were due to occur just out of sight on the far side of Jupiter, but the affected regions were expected to rotate into view within minutes. As each fragment hit, it was expected to explode at some depth into the atmosphere, releasing the equivalent of hundreds of megatonnes of energy.



Fragments Q_1 and Q_2, as seen by the Hubble Space Telescope.

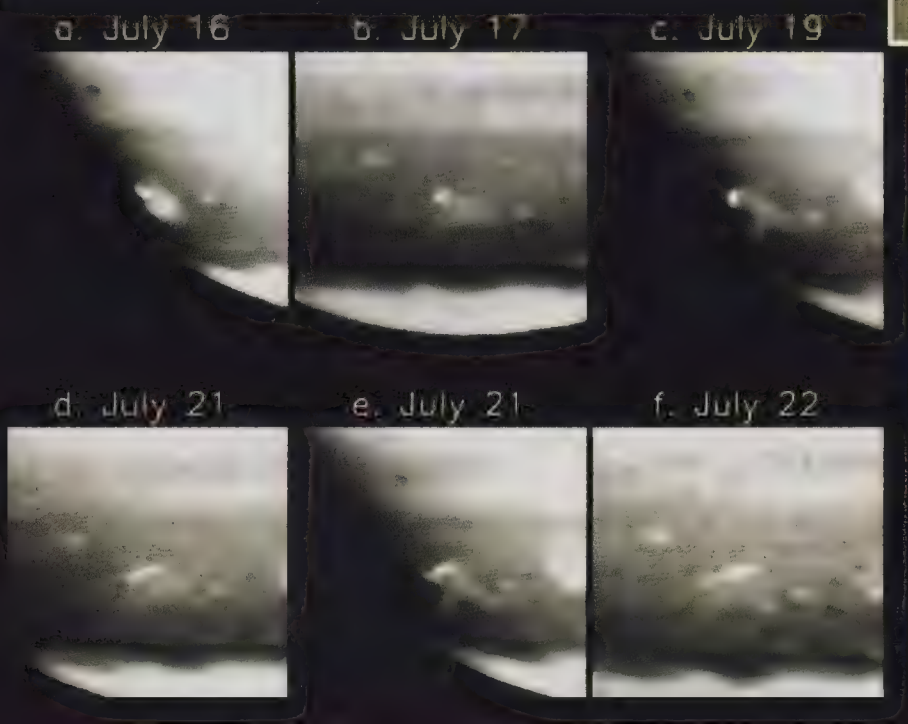
The comet hits . . .

Never before have we witnessed such a spectacular occurance right in our own celestial backyard. As a dramatic demonstration of our solar system as a dynamic, evolving region of space, and not a static system, the cometary crash generated renewed interest in planetary science. Virtually every observatory with a view of the southern skies, aimed their telescopes at Jupiter during the week of July 17 to 22. On the next few pages we present a portfolio of spectacular images from around the world.

Here in Australia we were perfectly located to view the impacts. The image below was made by Peter McGregor with the Australian National University's 2.3-metre telescope at Siding Spring in NSW. The infrared image shows the giant fireball which erupted following the impact of fragment G.

These six images (right) were made with the Anglo-Australian Telescope at Siding Spring Observatory using the award-winning IRIS infrared camera. They run from left to right, top to bottom. Frames 1, 2 and 3 show the impact sites of fragments A, E+F, H and G, with the Great Red Spot just above shining brightly at this wavelength. The bright feature on the left hand edge is actually the moon Europa coming into view; it can be seen passing in front of Jupiter in the following frames. In frames 4 and 5, Jupiter has rotated enough to bring the impact points of fragments K and C into view on the left edge. Frames 5 and 6 also show the moon Io passing in front of the planet.

This series of images (below), which spans more than five days, was obtained with the Hubble Space Telescope. A filter was used to reveal fine detail in Jupiter's upper atmosphere. The images show the development of the material ejected from site A, formed by the impact of the first fragment of Comet Shoemaker-Levy 9.



The remarkable resolving power of the Hubble space telescope enabled the Hubble Comet Team to record images such as this one of the fragment A impact site (above); the after-effects of the impact are clearly dissipating.

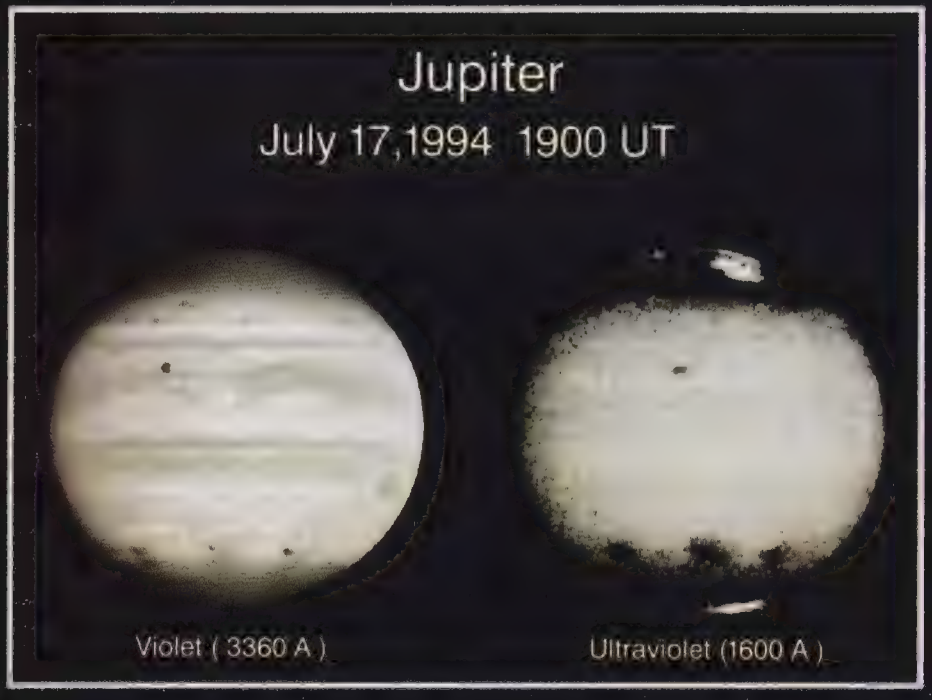
Impact!

The main picture (right) shows the King of the Planets with its new black spots - eight impact sites are visible. From left to right are the E/F complex (barely visible on the edge of the planet), the star-shaped H site, the impact sites for tiny N, Q1, small Q2, and R, and on the far right edge the D/G complex. The D/G complex also shows extended haze at the edge of the planet (bottom right). This Hubble Space Telescope picture shows features that are are less than 200 kilometres across - not bad considering that the planet is 800 million kilometres away.

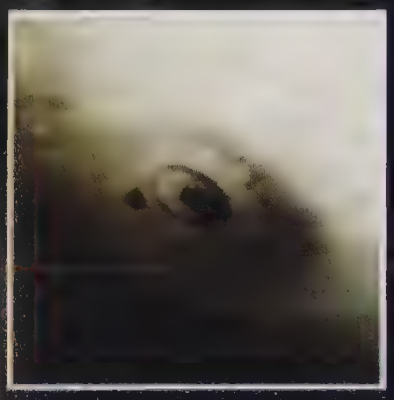
The picture below shows a 'close up' of the impact sites of fragments D and G. The picture has been computer processed to correct for the curvature of the planet, so that the spot appears flat, as if the viewer were hovering directly overhead. The large feature was created by the impact of comet fragment G; the smaller feature to the left was created by the impact of fragment D.

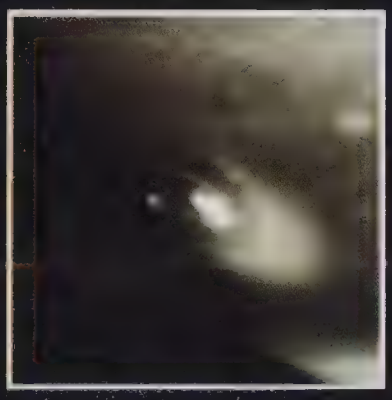
The dark crescent, nearly 12,000 kilometres across, was produced by material thrown high into Jupiter's stratosphere by the explosion created by the G impact. The inner ring might be a sound wave expanding from the site of the explosion.

This image (above) made in infrared light was taken shortly after the impact of comet fragment R. The brightest spot in the planet's southern hemisphere is the impact region. The other dimmer spots are previous fragment impacts. The bright spot in the northern hemisphere is the Jovian moon Io. The image was made by a team using NASA's Infrared Telescope on Mauna Kea Mountain in Hawaii. Images in the infrared reveal heat produced by the comet fragment as it releases energy during its plunge through Jupiter's atmosphere.



These images (left) show impact sites C, A and E; the moon Io is seen crossing above the centre of the disc, and the famous Great Red Spot is near the right edge of the planet. The ultraviolet image looks deeper into the atmosphere than does the visible light image; aurorae are visible near Jupiter's poles, caused by the interaction of charged atomic particles with the upper atmosphere. By tracking the impact regions, astronomers will for the first time be able to measure accurate wind velocities and directions in Jupiter's atmosphere.





Two images of the impact sites of fragments D and G (left) taken at different wavelengths. The large feature was created by fragment G as it entered the atmosphere from the south at a 45° angle. The smaller feature to the left was caused by fragment D.

This spectacular image (right) was taken at the Calar Alto Observatory in Spain; it shows the fireball (left-hand edge) from the impact of fragment Q.

A mosaic of images (below) from the W.M. Keck telescope in Hawaii shows the views before, during and after the impact of fragment R. Keck detected the flash from impact R: it lasted about 20 seconds. Eight minutes later, a plume appeared over the edge of the planet, brightened considerably and faded again over a period of about eight minutes.

Three views of Jupiter and the comet impact sites. Sketches by Paulineke Nolan.

The backyard view . . .

'It was like something out of the film 2010!', said Andrew Murrell, an amateur astronomer from NSW. Andrew was one of a privileged few who witnessed the most spectacular aspect of the S-L 9 impact: a plume arching out of the side of the planet as the K fragment slammed into Jupiter's atmosphere. Andrew was using a 50cm telescope called 'Hector'. 'I've seen a lot of spectacular sights through Hector, but the impact plume was the most incredible thing I've ever seen.' Amateurs wanted to observe the impacts not to make scientific observations, but just to see for themselves. They weren't disappointed.

The first hint of what was to come was on the Sunday evening. Earlier that day the first chunk of Shoemaker-Levy 9 struck the planet. Fragment A was small compared with the other fragments, but it left what looked like a grey smudge in the southern hemisphere of the planet. The feature was a challenge to even moderate sized telescopes, but several observers were surprised to see anything at all.

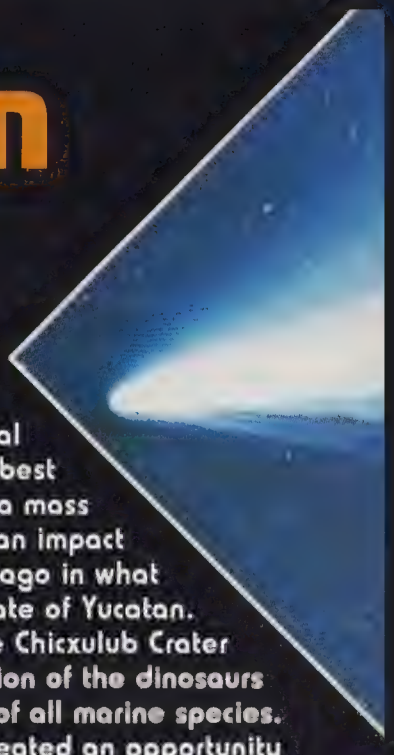
Photo by A. Surma

Jupiter's ten-hour rotation period meant that while several other fragments had fallen into Jupiter, the next impact visible from eastern Australia was fragment G . . . and it was huge! An intensely dark spot surrounded by a grey oval plume. Those who saw it were later able to compare their impressions with photographs from the Hubble Space Telescope, so confirming their observations. Tuesday night saw amateurs around the country watching keenly for the much-publicised impact of fragment K. Although the highly speculative brightening of Europa wasn't seen, Murrell and others saw a plume appear like a bright lump on Jupiter's edge. It remained visible for about three minutes, and was about the size as one of Jupiter's moons. A few hours later the impact site rolled into view. It was enormous: very dark in contrast with the pale, cream coloured clouds. It looked like someone had taken an enormous bite out of the side of the planet!

As the week progressed, the remaining fragments continued to bombard Jupiter, several piling one on top of the other so that the individual sites couldn't be distinguished. Over the following few weeks the mass of destruction began to spread around Jupiter. Carried by the strong atmospheric currents the remains of the G-impact were spread over several tens of degrees longitude, looking like a short section of a newly formed cloud belt.

The event is now over. Yet while most amateur observers will once again turn their attention to more distant objects, every once in a while they'll point their telescopes toward Jupiter, and remember a week of intense excitement, long after the atmospheric scars have faded. *Geoff McNamara*

Could this happen to the Earth?



Like the other planets in the solar system, the Earth is constantly pelted with impacting debris. The debris ranges in size from tiny particles of interplanetary dust to larger comets and asteroids that cause catastrophic events. There is evidence that asteroids, comets and a constant rain of interstellar dust particles brought life-forming elements and compounds to the Earth. Early in the Earth's history, comets may have helped form the oceans.

Cosmic impacts are a natural part of geologic history. Large impacts on Earth are extremely rare, but they can do tremendous damage, exceeding that of any other known natural disaster. The atmosphere effectively shields us from most impacts that have less energy than 10 megatonnes of TNT, which corresponds to the impact of a 30-metre diameter comet or asteroid. Larger objects penetrate to the lower atmosphere or surface where they explode, causing tremendous local damage.

The Earth has been hit before - one impact 65 million years ago might have wiped out the dinosaurs.

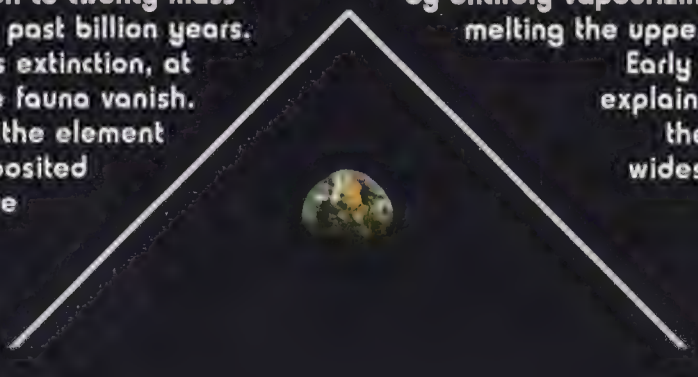
If the impact is large enough - approximately one kilometre in diameter - it can lead to global environmental damage. The damage is primarily caused by vast amounts of dust lofted into the atmosphere, but damaging chemical changes in the atmosphere and oceans also occur and hot ejecta can ignite large-scale fires. The largest impacts - by objects up to 15 kilometres in diameter - have led to mass extinctions.

There have been from ten to twenty mass extinctions on Earth in the past billion years. In a mass or major species extinction, at least 25 percent of marine fauna vanish. Unusually high amount of the element iridium, thought to be deposited by the cosmic impactor, are associated with several of these events. The best documented record of a mass extinction caused by an impact occurred 65 million years ago in what is now the Mexican state of Yucatan. The impact formed the Chicxulub Crater and led to the extinction of the dinosaurs and more than half of all marine species. The event also created an opportunity for an 'explosion' of new species, including mammals.

The Earth's impact history can be derived from the lunar crater record. The Earth and Moon share the same part of space and have identical impact histories. The Moon, however, has been geologically inactive for the past three billion years and preserves the impact record much better than Earth. The current impact rate can also be estimated from studies of the comets and Earth-crossing asteroids that astronomers discover and track.

Many scientists now think that the Moon was formed when a Mars-sized body hit the Earth early in its formation. The impact thrust enough crustal debris into orbit to coalesce and form Earth's orbiting satellite.

In the first billion years of Earth's existence, colossal bodies crashing into it may have delayed the origin of life. The largest and most rare bodies would have destroyed any life which had already begun by entirely vapourizing the early oceans and melting the upper layers of Earth's crust. Early giant impacts may also explain the later separation of the continents and Earth's widespread volcanic activity.



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9.00pm on October 1
8.00pm on October 15

For dates in between, the time can be worked out by simply adding or subtracting four minutes per day. Note that as the night progresses, stars on the western edge of the chart set below the western horizon and others rise above the eastern horizon: this is the effect of the Earth's rotation.

HOW TO USE THE CHART

Hold the chart over your head and align it so that the bottom of the page faces south. What you see on the chart then corresponds to the sky for the time listed at the top right-hand corner of the page. The centre of the chart is the point directly overhead, the circumference is the horizon, and the light-blue band is the Milky Way. The chart is based on the latitude of Sydney, but can be used without too much distortion from 20° to 50° south.

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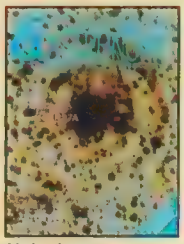

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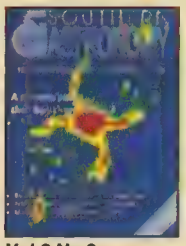

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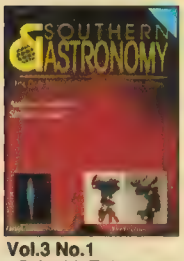

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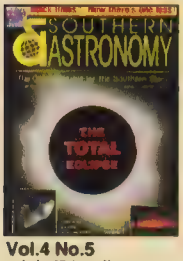

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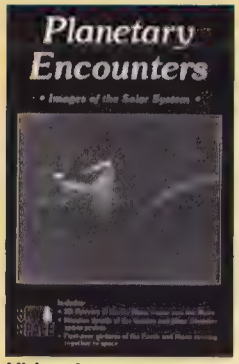

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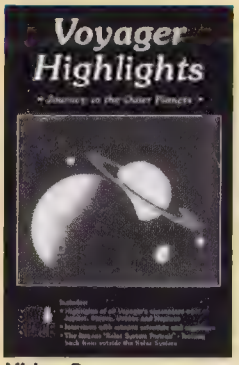

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SKY & SPACE Magazine PRESENTS

MAN ON THE MOON

Probably the greatest moment in the history of the exploration of the solar system, occurred 25 years ago this year. On July 21, 1969, humankind first set foot upon another planet. Millions of enthralled Earthlings held their breath at the fateful moment when Neil Armstrong, Commander of the flight of Apollo 11, first stepped onto the dusty surface of the Moon.

It's hard to believe that 25 years have passed since that historic day. Whole generations have grown up without knowing the excitement and tension of such a great human adventure. Perhaps the only other mission of solar system exploration that even comes close to recapturing that excitement and wonder has been the amazingly successful Voyager probes to the outer planets. It is fitting, then, that the 25th anniversary of Apollo 11 was not forgotten, but was instead celebrated in many countries in a variety of ways.

Celebration

Australia, of course, played an important role in the missions to the Moon. The NASA tracking stations situated on Australian soil were vital in providing communications with the astronauts as they journeyed to and from the Moon. Names such as Honeysuckle Creek, Carnarvon, and Woomera, still evoke a sense of wonder and of pride to those who were around in the 1960s and early 1970s. The famous Parkes radio-telescope of the CSIRO also played an essential communications role, boosting the receiving capabilities of NASA's world-wide tracking network. Many Australian scientists also took part in various aspects of the lunar missions (see Ross Taylor's article in this issue).

So it was that the Australian Space Office and NASA decided to arrange a special celebration of the 25th anniversary here in Australia. The main events were to take place in Sydney, and SKY & SPACE was asked to arrange all the festivities.

Together with the Australian Space Office and the Australian International Space School, SKY & SPACE sponsored the visit to Australia of NASA's longest-serving astronaut, Captain John Young.

John Young (right) and SKY & SPACE's Jonathan Nally during the moonlanding anniversary celebrations.

Captain Young is the only Apollo astronaut still serving with NASA. He was selected as an astronaut in 1962. He has flown in space more times than any other person - he was on Gemini missions 3 and 10, Apollo missions 10 and 16, and Space Shuttle flights STS-1 and STS-9. He was also on the back-up crew for five other spaceflights. Young has put in over 13,500 hours in training, including hundreds of simulation runs. He has logged more than 12,400 hours flying time in propeller aircraft, jets, helicopters, rocket jets, and spacecraft, including 835 in space.

The astronaut's astronaut

Young's first flight into space was with fellow astronaut Virgil 'Gus' Grissom aboard Gemini 3. This was the first manned Gemini mission, and was a mainly a test of manoeuvring systems and re-entry procedures.

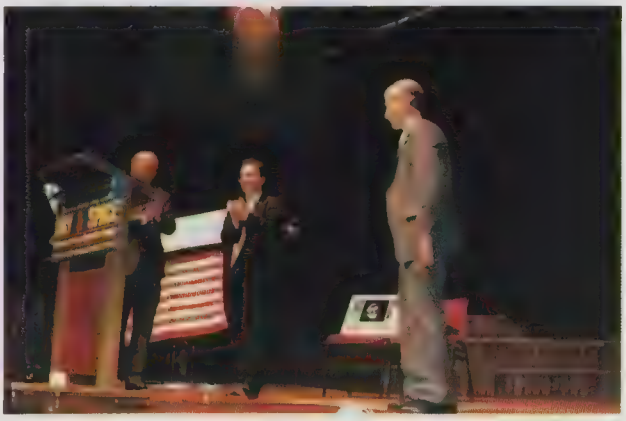
His second flight was Gemini 10, during which he and Michael Collins accomplished the first rendezvous with two separate docking targets in orbit. The mission was a vital test for the Apollo programme, providing invaluable experience in rendezvous and docking techniques.

In the final dress-rehearsal only two months before the flight of Apollo 11, John Young was the command module pilot for Apollo 10. The crew circled the Moon, testing all of the mission parameters short of actually landing on the Moon itself. Apollo 10 was the first to attempt rendezvous and docking procedures in lunar orbit.

His fourth space flight, Apollo 16, was a lunar exploration mission. Young and Charlie Duke set up scientific experiments on the lunar surface and using the lunar rover explored the Descartes lunar highlands. They collected almost 100 kilograms of rock and drove over 25 kilometres.

Nine years after walking on the Moon, John Young was commander of the first space shuttle flight. The 36-orbit mission of space shuttle Columbia was the first time a winged re-entry vehicle had returned from space to a runway landing.

Captain Young's sixth flight was as commander of the ninth space shuttle flight, which was the first mission to incorporate the Spacelab experiment module in the cargo bay. The mission conducted experiments in many fields of science, and collected more scientific data than from all previous Apollo and Skylab missions.



***Top:** John Young (right) captivated an audience of 1,400 people at the SKY & SPACE Man on the Moon Evening at the Sydney Town Hall on July 14. The night was compered by the ABC's Robyn William and SKY & SPACE's Editor, Jonathan Nally. **Above:** Captain Young also spent time in Canberra where he spoke to 300 people at the National Science and Technology Centre, as well as taking part in anniversary ceremonies; he is seen here with Mike Dinn, the outgoing director of the Canberra Deep Space Communications Centre.*

Australian celebrations

Several months of very hard work, by SKY & SPACE with lots of coordination with NASA and the Australian Space Office in Canberra, culminated in a very successful week of celebrations in mid-July. John Young, the only Apollo veteran still serving as an astronaut, was the natural choice to come to Australia to take part in the activities.

We were determined to ensure that the widest audience possible was made aware of the anniversary and of the celebrations planned. A comprehensive media schedule was arranged, involving television appearances (The Midday Show, The Denton Show, and numerous news programmes), more than a dozen radio interviews, and hundreds of stories in local, state and national newspapers and magazines. The media coverage we arranged created tremendous interest; many newspapers ran nostalgia sections with comments from readers, ranging from those who remembered exactly what they were doing when man first stepped on the Moon, to those who didn't know (but should have known!) who Neil Armstrong was!

On Tuesday, July 12, Captain Young spoke to a packed theatre at the Powerhouse Museum. Over 300 people were kept enthralled by Young's fascinating, and very humorous stories of his adventurous career. The following day he returned to the Powerhouse for a unique live satellite link-up with another astronaut in Washington. At the Sydney end was an audience of over 300 school students (from the Australian International Space School and Powerhouse member schools), plus John Young and the only Australian-born person to fly in space, astronaut Paul Scully-Power. At the Washington end was Charles Walker, a three-time astronaut, who spent about 30 minutes answering questions from the students. At the conclusion of the satellite link up, Young and Scully-Power answered more questions from the students, including some Russian students visiting the space school.

Later that day, Captain Young took part in a ceremony in Martin Place, where he transferred to Senator Chris Schacht a precious piece of Moon rock from the Apollo 11 collection. The rock will be put on permanent display at the visitors' centre at the Tidbinbilla Tracking Station near Canberra.

The major event of the week was a public talk at the Sydney Town Hall on the evening of Thursday, July 14. An almost capacity crowd of 1,400 people attended the SKY & SPACE Man on the Moon Evening. A spectacular audio-visual introduction, produced by SKY & SPACE's Glen Nagle and video specialist Martin Thorne, set the tone for the evening. The compere, Robyn Williams, from the ABC Radio's Science Show, then spoke of his early days at the ABC, where one of his first duties as a young researcher was to compile information on the then current Moon mission - Apollo 16, John Young's second flight to the Moon.

With that introduction, John Young then held the audience spellbound for 50 minutes while he described his flights in space, his experiences on the Moon, and the future for space exploration. This was followed by about 40 minutes of questions from the audience.

Young is a great advocate for the continuing investigation of our solar system, and a keen amateur astronomer. He's also a devoted environmentalist (though he shuns that word), with a firm belief that the knowledge and technologies we derive from spaceflight will prove vital to solving our environmental problems here on Earth. He used as an example some of the leading research being conducted in NASA laboratories into the cultivation of food plants in future Moon bases: farming methods have been devised that are several hundred times more efficient than those currently used here on Earth. It's easy to see the benefits we could all gain by implementing these spaceflight-inspired technologies on our own planet.

SKY & SPACE was thrilled to have played such a major role in the Apollo anniversary celebrations. We thank John and Susy Young for coming to Australia to help us all remember that amazing moment when humankind took its first step to the stars. S&S

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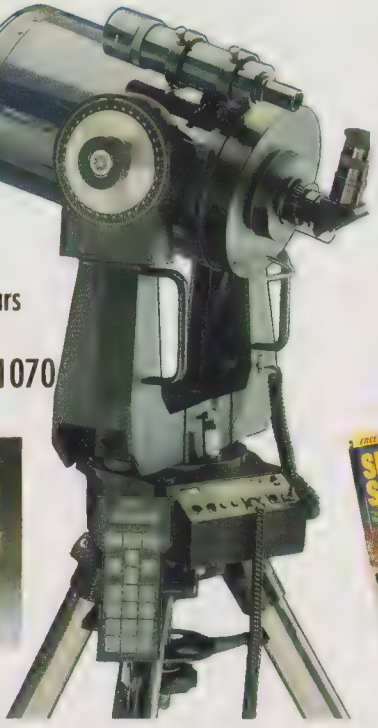

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A National Space Program for the 1990s

by Malcolm H. Farrow

Australia has been involved in the space race from the very beginning. Yet despite many early successes, we still have a long way to go to fully capitalise on the opportunities in space. The head of the Australian Space Office, Malcolm Farrow, gives us an insight into the Government's plans to revitalise Australian space industry and space science.

As we steadily push back the frontiers of space, the opportunities unfolding are almost as limitless as space itself. Without most of us even realising it, space technology has become a daily part of our lives. And in a country as vast and sparsely populated as Australia, it has also become an essential part of our lives. With this in mind, the Commonwealth Government has made a major commitment to developing a viable and effective space industry well into the 21st century.

Our history in Space

Australia was one of the first countries to grasp space technology, as long ago as the 1940s, in cooperation with other countries. Within two decades our fledgling industry was at the forefront of the space race. In 1967, Australia was only the third nation to build and launch its own satellite (WRESAT) from its own soil. We made history in 1969, with our key role as ground support for the first manned lunar landing. The Woomera Rocket Range became famous in the 1950s and 1960s as the second largest launch and tracking facility in the West, serving as the base for the United Kingdom and European launch (ELDO) activities.

To put some perspective on Australia's contribution to the joint project with the United Kingdom, Australia expended the equivalent of $2.262 billion during the entire period of operation, while the UK's contribution was a mere $982.1 million.

Australia gained considerable experience and expertise during this time through its collaboration in these programmes. However, with the decline of the UK's space effort and the transfer of the ELDO launch capability to Kourou in French Giuana in the early 1970s, local launch service and associated expertise, gained from the joint ventures centred at Woomera, was dispersed.

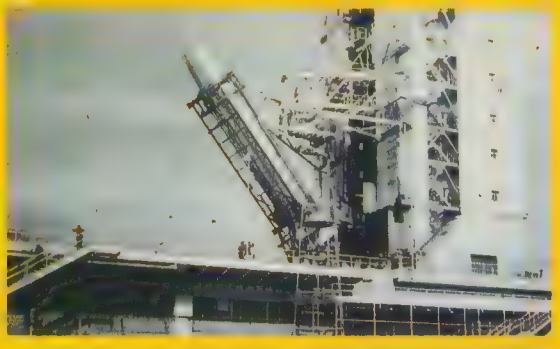
In the ensuing years, key individuals established research programs into various space technologies. For example, Australia's worldwide pre-eminence in hypersonics, particularly shock tunnel technology, was developed during this period.

Throughout the 1970s, a considerable Australian space science and technology activity was developed in support of other countries' programs, notably operating ground support facilities for NASA's planetary missions, particularly the lunar landings. This partnership with NASA continues today under a country to country agreement with the USA and is valued at approximately $12 million dollars annually. Some 150 Australian personnel are employed at the NASA tracking stations within Australia. These are managed by the Australian Space Office and support deep space missions such as Voyager, Magellan, Galileo and Ulysses.

At the same time, Australia was quickly adopting space applications in areas such as meteorological forecasting, satellite communications and remote sensing. As an early user of satellite remote sensing technology, Australia established collaborative arrangements with the USA, France, Japan and the European Space Agency to acquire data from a number of satellites. In remote sensing particularly, Australia tailored applications to meet local conditions and needs.

In the 1980s, Australia again set about developing an indigenous national space industry, based on space science and technology.

Australia developed one of the world's most advanced domestic satellite communications networks through AUSSAT (now OPTUS), with the launch of a series of dedicated satellites. We were a founding member of INTELSAT - a multinational series of telecommunications satellites - and INMARSAT - a constellation of satellites providing mainly maritime communications.



A Europa rocket on the launch pad at Woomera during the 1960s.

This saw Australia take on a more centralised and national focus with the establishment of the National Space Program in 1986. The Program was one of several recommendations made to Government by the Academy of Technological Sciences in a review of Australia's space activities. It was decided the Commonwealth Government should play a leading role in building a viable space sector. The National Space

Program enables the Government to coordinate space related science and technology activities on a national basis.

Trends in space development

Since 1986, the National Space Program has been revised according to prevailing domestic and international conditions. In a formal review of the Program in 1992, a Government appointed Expert Panel identified a number of international trends which have major implications for the future of Australia's space industry.

The Panel found that governments around the world are less inclined to fund space spectaculars but are still eager to use space technologies to address national and global problems such as environmental protection. Governments are also using space programs as vehicles for international cooperation yet increasingly are looking to the private sector to fund space activities. And alarmingly, there is a move by the international community to close the door on the 'open skies' policy - the free distribution of information, particularly remote sensing data.

Underpinning these trends are various political and economic considerations. Many nations believe that by developing leading edge space technologies they will encourage the development of industries to guarantee long term competitive advantages in the international market place.

Possibly the greatest determinant of current and future civil space trends is money. Escalating costs of traditional space flight activities have made space transport the province of a few nations. To combat this, co-operative efforts between nations, governments, and commercial partners are being formed in order to diffuse costs and distribute the public benefits.

The Expert Panel concluded that no modern nation could afford to be without an effective space program which both served the public at large and enabled the private sector to expand its role in space activities.

Following the 1992 review of the National Space Program, the Commonwealth Government replaced the existing Australian Space Board with an enlarged Australian Space Council and established it formally under legislation - Australian Space Council Act 1994. The Council comprises members from industry, research organisations and government agencies, reflecting key stakeholders of the Program.

The objectives for the National Space Program are set by the Council while the Australian Space Office, the executive arm of the Council established in 1987, manages and implements the Program.

The European ERS-1 earth observation satellite - Australian-made scientific instruments are an important part of the ERS series of satellites.

Planning for the future

The objectives for the Program are to be set down in the form of a five year plan which will be developed and then reviewed annually by the Australian Space Council. The plan will, in effect, become the blueprint for the National Space Program. It will incorporate a five year action list of initiatives in the areas of earth observation, space communications, global positioning, launch services, and space related science and international activities. These initiatives will be designed to enhance Australia's space capabilities and capitalise on emerging domestic and international opportunities.

"The Five Year Plan will become the blueprint for initiatives designed to enhance Australia's space capabilities."

The objectives of the Five Year Plan (1994 - 1998) will be based on the national goals of contemporary Australia. These goals include equity for rural and urban Australians in the provision of basic services, ecologically sustainable development, high value added export industries and regional development in the burgeoning Asia Pacific market.

In the area of earth observation, it is expected that the Five Year Plan will identify several opportunities for Australia in the marketing and value adding of remote sensing technology. Remote sensing enables us to observe the earth through data obtained from satellites and aircraft. The data is processed as imagery which provides detailed information on the earth's land surface, oceans and atmosphere. Currently remote sensing data is used mainly by government or government related agencies in areas such as environmental protection and agricultural management. In the private sector, mineral exploration companies have long been significant users of remote sensing data. To date though, this data has been difficult and expensive to access by individual and smaller end users.

The Five Year Plan is likely to establish a national remote sensing data network that can be easily accessed by organisations and individuals alike. The aim is to set up a network that will allow end-users, anywhere in Australia, to access data at an affordable cost; download it to their own PCs; and through an application software package, manipulate it for their own purposes. The Australian Space Office has engaged a consultancy to advise the Office on the type of network that would best meet these objectives.

Training people to interpret remote sensing data is one of the elements of the proposed Five Year Plan and represents an opportunity to provide value added services both here in Australia and in the rapidly growing Asia Pacific market. Education services will be expanded in a national education program to meet the expected growth

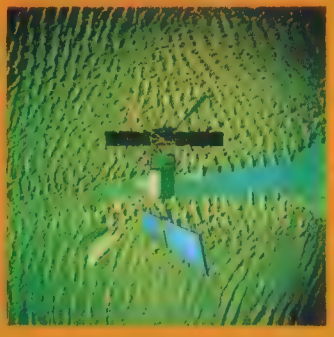
in demand, particularly in the Asia Pacific.

A consultancy is currently advising the Space Office on the feasibility of establishing a national education program while a third consultancy is looking specifically at ways of developing the market for value added services.

The ASO is supporting a plan by an Australian joint venture to launch Australia's first privately owned microsatellite network and this could become an element of the forthcoming Five Year Plan. KITComm Pty Ltd, a joint venture between Queensland based Kennett International Technology Pty Ltd and several private investors, is to team with the American company PacAstro Inc to provide low cost launches from a new northern Australian launch site near Darwin. A constellation of nine microsats will form one of the first low earth-orbiting communications satellite systems, scheduled for launch in early 1996. The network will be the first to service equatorial regions in the Southern Hemisphere for low level data transmission.

Getting off the Ground

Part of the Australian Space Office charter is to help get space projects off the ground with direct funding and coordination of key players in the industry. One such project is the research and development of the scramjet engine for hypersonic space planes. The research is being undertaken at the University of Queensland in conjunction with the Australian National University. The Australian Space Office has provided interim funding for the project and is actively seeking an international partner for the ongoing funding and commercialisation of the project.



Europe's ERS series of satellites are helping scientists keep track of Earth's resources.

A hypersonic space plane would have the capability to leave and re-enter the atmosphere at speeds of up to 11 kilometres per second. As an air-breathing engine, the scramjet extracts its oxygen requirements from the atmosphere. By removing the need to carry liquid oxygen fuel, it makes it possible to significantly cut launch costs.

At an international level, the Australian Space Office helps to foster cooperation through inter-country projects such as the Along Track Scanning Radiometer (ATSR) series. The Office negotiated Australia's involvement in the development and manufacture of a series of instruments for the European Space Agency, as part of an international research project. The project is putting together a data base of sea surface temperatures over a ten year period, to be used in research into global warming trends. The ATSR instruments, deployed aboard European Space Agency satellites, are used to gather highly accurate sea surface temperature measurements and to monitor global vegetation.

At a cost of around $12 million, Australia will provide about one third of the Advanced Along Track Scanning Radiometer (AATSR), which will be flown on the European ENVISAT-1 spacecraft in 1998. Some of the sub systems of the AATSR, the third in the series, will be manufactured by Australian companies under contract to the Australian Space Office.

Australian companies and university research centres are being nurtured by new joint government-industry programs.

Australia provided the Digital Electronics Unit of the ATSR, the first instrument in the series, which is currently in orbit on the European Space Agency Satellite ERS-1. That instrument is returning images and sea surface temperature data of the highest quality. Two major subsystems of the second instrument in the series, ATSR-2, have also been supplied by Australia and will fly on ERS-2 this year. Participation in projects such as this should allow Australia to access data produced by such projects.

The ATSR project is putting Australia on the international map with an important inter-country partnership and experience in meeting international Space Qualification Standards. At the same time, it is helping to expand our indigenous space capability. The project is also affording Australia a unique opportunity to tap into valuable research data which may have far reaching environmental and political implications.

Going Commercial

In the fallout from the ongoing lack of commercial space products available from Australian industry, the private sector has been extremely reluctant to invest in space technology development. The Australian Space Council is determined to turn this situation around. The Council is funding the Space Industry Development Centres (SIDC) program, a major component of the National Space Program, to accelerate the development of commercially successful space products for domestic and international markets. The program encourages research and development through cooperative partnerships between research institutions and private industry, by direct funding of centres of expertise, based in tertiary institutions.

The program is administered by the Australian Space Office and three centres have been funded since 1992. They are: the Australian Space Centre for Signal Processing at the University of South Australia in Adelaide; the Space Centre for Satellite Navigation at the Queensland University of Technology in Brisbane and the Space Centre for Microwave Technology, based at Griffith University, also in Brisbane.

Many factors have worked to re-shape the Australian space industry since its inception more than 50 years ago. As we approach the third millennium, financial pressures are weighing more heavily than ever. The Federal Government has demonstrated its renewed commitment to the Australian space sector through the adoption of the findings of the Expert Panel Review and the appointment of the Australian Space Council. The future of our industry though will rest largely on the shoulders of the Program's stakeholders and their ability to come together as joint partners in space. S&S

Malcolm Farrow is Executive Director of the Australian Space Office. He has served with the Department of Trade and Resources, working on policy involved with international issues. In 1980, he served as Assistant Secretary, Trade Policy and International Organisations Branch, where he was responsible for negotiations on trade issues arising in international multilateral organisations. Later he worked in the UK as Director, Policy and Research for the International Tin Council. Returning to Australia in 1987, he has held several senior positions with the Department of Industry, Technology and Commerce.

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Coona gets a public observatory

Opening to the public by mid-September, the new Skywatch Night 'N' Day Observatory at Coonabarabran will hold its official opening ceremony on Sunday, October 23.

Designed and constructed to complement the cluster of professional observatories at nearby Siding Spring Mountain, Skywatch is the brainchild and dream come true from Max Mapleson. During the past year or so, Max, and wife, Pat, became committed to the notion that there was an opening in Coonabarabran for an observatory which could be available to the public for day and night viewing.

Tony Marx and Robyn Keech, long-time friends of the Mapleson's, quickly became enthused with Max's idea and it wasn't long before the Skywatch idea was developed. The company was set-up in January, with another local resident, Wilf McBeath, forming the fifth partner.

Construction began in March. In an effort to maintain the character of the bush setting it was decided to use local natural materials as much as possible. Mud-brick, cypress pine and ironbark timbers constitute the basic structural components. The main building houses the reception area, a retail section and a display area. A cafe/restaurant is currently under construction.

Of eyecatching design, the 6.7-metre-diameter geodesic dome is mounted on a 6-metre tower. Within the dome, atop a steel pillar, is the 31cm f/5 Newtonian telescope on a German equatorial mount. Location and identification of space objects is computer-assisted using a JMI NGC-MAX. Smaller telescopes and binoculars are also available to visitors for use on the outdoor viewing platform. An EX-3 planetarium with a 3-metre projection screen is installed at ground-level in the dome tower.

Other attractions will include a hands-on microscope display and a computer bank where visitors may enjoy a variety of programs and games.

As the Skywatch Observatory will be open to the public by mid-September, visitors to the SKY & SPACE ASTROFEST in October are most welcome to call in and inspect the complex.

For further information on Skywatch, phone Max Mapleson on (068) 422 506 or fax (068) 422 978.

Above: *The Skywatch Observatory, taking shape at Coonabarabran, NSW.*

Teachers' conference a success

Southern Star Education - a mobile planetarium service, operated in southern Queensland by Paul Floyd - teamed up with the Brisbane Astronomical Society in April to run a special astronomy workshop for teachers in the south-east corner of Queensland.

Dozens of teachers responded to the invitation to attend; they were kept busy all day with practical demonstrations, lectures and sessions in the planetarium.

Keynote speaker was Dr Ian Ginns from the Queensland University of Technology. Dr Ginns described many methods of teaching astronomy in an interactive fashion and had the participants construction an astrolabe from an assortment of elements including a protractor, string, sticky tape and a straw.

A series of other speakers then took the teachers on a verbal tour of the universe, discovering along the way that one day is really not enough to cover all that needs to be covered! The operation of telescopes was demonstrated, solar observing conducted and night-sky tours in the planetarium rounded off the daylight activities, followed by some night viewing.

It was a very successful event, attracting teachers from as far afield as Southport, Toowoomba and Yeppoon. It was so successful, in fact, that a second Southern Star Conference will be held next year on March 11 at the Grace Lutheran College at Redcliffe, near Brisbane. The Brisbane Astronomical Society would like to hear from teachers who are interesed in attending, particularly those who might like to give a presentation. Write to: The Hon. Secretary, Brisbane Astronomical Society, PO Box 204, Morningside, Qld, 4170, or the Hon. Organiser, Southern Star Conference, Lot 25, Doncaster Dr, Beechmont, Qld, 4211; or telephone Tony Surma on (07) 274 5073 or Paul Floyd on (075) 333 610. **Tony Surma.**

SKY & SPACE Magazine is proud to be a supporter of the Southern Star Conference.

Below: *Teachers taking part in the Southern Star Conference learn how to make an astrolabe, and how to watch the Sun safely.*

Society Meetings

Astronomical Society of NSW
Strathfield, Sydney

Sept 16 - Prof. John Davis, Uni. of Sydney, will present a lecture on the Sydney University Stellar Interferometer.

Oct 13 - How to build a Dobsonian telescope

Oct 21 - Dr Joss Bland-Hawthorn, Anglo-Aust. Obs., will present a lecture on quasars. Tel: (02) 332 4735.

Space Assoc. of Aust.
Moorabbin, Melbourne

Nov 1 - A presentation on Australia's only active liquid-fuel rocket project.
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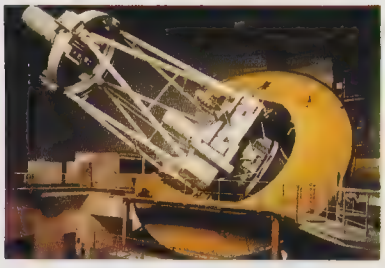

20th birthday of the AAT!
Australia's largest telescope, the Anglo-Australian Telescope, turns 20 this year. Two people who helped make the AAT a world- leader, David Allen and Doug Cunliffe, share with us the excitement of two decades of discovery.

Shooting the Moon.
Did you know that Australia shoots laser beams at satellites and the Moon? Malcolm Miller takes us behind the scenes at the Orroral Valley Laser Ranging Station, a little-known but important Australian scientific establishment.

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A group of Queensland amateurs gathered together under the clear winter skies, to experience a once-in-a-lifetime celestial sight.

During May, 1994 in the dark of the Moon, members of the Southern Astronomical Society (Qld), travelled south almost to the NSW border to secure dark skies. The chosen observing site was a serene, grassy meadow partly encircled by a tree-lined, crystal clear stream. In the opposite direction there was a dramatic, rocky mountain which blocked Venus at the end of twilight.

Sky darkness and transparency were so excellent that the zodiacal light blazed above both the western and eastern horizons and could readily be seen traversing the whole heavens, forming a counter-glow near Jupiter. To see the zodiacal light right across the sky, it is important to make sure it does not run close to the Milky Way and to look for the contrasting darker sky adjoining its boundaries.

Our telescope apertures ranged from a moderate 20cm through to my 46cm. Many telescopes had computer-aided object acquisition systems which enabled the observers to find objects within seconds! These 'organised' observers were able to spend virtually all their time observing instead of flipping through catalogues, star charts and straining their necks star-hopping through dewy viewfinders. The extraordinary increase in the number of objects observed and the ease operation which CATs (computer-aided telescopes) provide has to be seen to be appreciated.

Although it was May, temperatures were pleasant, requiring only modest amounts of clothing, though dew was heavy by midnight as everything cooled to ambient air temperature. Various dew zapper designs - from modified jug elements running on 12 volt car batteries to the improvisation of heated rocks and tent pegs - were employed to keep optics that one degree above the air temperature to eliminate condensation. The seeing was perfect for all of the first night and good for most of the second night when there was no cloud at all.

Jupiter and Saturn and their accompanying moons hung stationary for seconds on end and through high-powered Naglers we experienced the almost unbelievable impression that we were 100 years in the future looking out of the lounge winders of an interplanetary cruiser's observation lounge! At high power through high-resolution optics, Europa's tiny, but distinct sphere, moved to the edge of Jupiter's massive cloud-covered disc to the ethereal music of Stardreams. We watched Europa's ink black shadow following faithfully to become an ellipse just before it departed company with Jupiter's cloud tops.

Late in the morning, as a slender New Moon was rising in the morning zodiacal light, Saturn was high in the sky and noticeably dimmer than we have seen it for well over a decade. Its rings are nearing edge-on and therefore not reflecting their usual degree of light back to us,

but they looked incredibly three-dimensional through large apertures.

On Saturday the 9th, meteors were raining from the heavens with most observers seeing 50 to 100 during the evening without any concerted effort. Many were bright but the grand-daddy of them all was a Steven Spielberg production! Around 3am, a bolide around magnitude -4 or brighter traversed about 80° of the south-western sky. Halfway along, it split into two and both pieces eventually exploded about 20° above the horizon. It was fast and it left a brilliant trail.

Remembering a bolide trail seen through 20x80 binoculars years ago that looked just like the complex contrail from a jet, I turned the 46cm telescope on this lingering trail before it faded from naked-eye visibility. Through the viewfinder it was bright and impressive and beginning to distort along its length. Through the 46cm telescope's eyepiece, it was absolutely remarkable! To the astonishment of all, there were two parallel trails which intertwined to form a rapidly expanding, long corkscrew that itself kept bending from one end to the other due to cross winds at high altitudes. As it lasted for about a couple of minutes everyone had the opportunity to move the 'scope up and down the trail's 'tracks'. The end turned into a loop and the double helix continued to expand until it became too faint to see.

No doubt the meteor was rotating rapidly as it entered the atmosphere and this caused the corkscrew effect, but why did the trail expand so rapidly in all directions? Was it caused by the shock wave, outgassing or some other reason? We had never heard of anyone seeing a bright meteor trail through a large telescope before and we were all glad we had the opportunity. Try it yourself the next you see one and let us know what you see.

Before the end of two exquisite evenings under pristine skies, we lay on the ground to observe the greatest spectacle of the night sky - a naked-eye view of the winter Milky Way culminating directly overhead. Naked-eye dust lanes, star clusters, nebulae and thousands of stars created a truly awe-inspiring sight to behold which no telescope sight can match.

Held firmly against the surface of our rotating world, we were looking thousands of years back in time through the spiral arms of our galaxy, gazing towards its core. The apparently innumerable stars we were seeing constitute only the tiniest fraction of a percent of the Galaxy's stellar population. Only the top 5% of stars as large or larger than the Sun and relatively nearby could be seen.

We couldn't help but contemplate if we were the only intelligent lifeform in the galaxy of just one of trillions. What unknown delights await humankind's future endeavours to explore and understand the cosmos, we thought.

And still the meteors fell as the morning zodiacal light brightened. Nights like these are what astronomers's dreams are made of. S&S

Gregg Thompson is one of Australia's foremost amateur astronomers and astronomy authors. He conducted the Deep Sky column in the early years of this magazine.

TECHNICAL TIPS by Steven Lee

Continuing his series on how to build a better telescope, Steve Lee looks at ways of securing the main mirror - by building your own mirror cell or modifying a bought one.

In the last two Technical Tips we looked at the optical parts of a Newtonian telescope; consider now the mechanical parts. There are really only four mechanical 'bits'; the primary mirror cell, the secondary mirror holder, a focusing mechanism and a tube to hold them all together. Surely they've evolved to their ultimate state? I think not!

What's wrong with them? Let's start with the primary mirror cell. The purpose of the cell is to support the mirror and to hold it securely in place. The cell must not distort the mirror in any way yet it must not allow the mirror to move, no matter how much it is waved about the sky. A reasonably difficult sounding exercise, but not impossible.

Mirror cell basics

As we all know, a three-legged stool is stable even if resting upon an uneven surface. The same principal is applied to our mirror cell. The weight of the mirror is supported on three points spaced at 120° and at an appropriate radius (0·707 of the mirror's radius) so that each point supports an equal weight of mirror. We can even go further and make these three points become the centres of further triangles and make 9-, 18- or even 27-point supports for heavier mirrors. This arrangement would be easy if our mirror remained flat, forever pointing at the zenith; but we need to move it about the sky. So we need some way of holding the mirror rigidly to its support system, and some clips to stop the mirror falling out if it is turned upside-down. We also need some mechanism to allow us to align our mirror with the other components of our telescope.

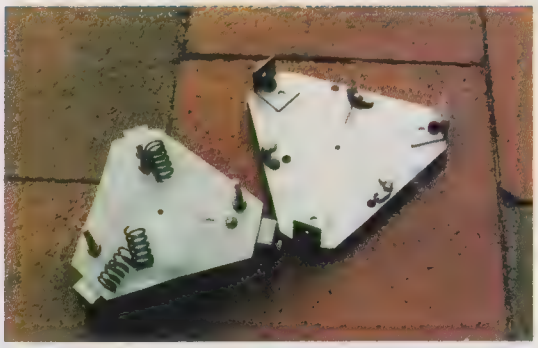
The classical cell was described in our May/June 1992 by James Pollock in his article on building a 15cm telescope. It consists of one triangular board to hold the mirror and another triangular board to hold it to the telescope. The top board has lugs which loosely clip over the top of the mirror to hold it down and the two boards are spaced by three springs; collimation is achieved by appropriate adjustment of the three screws. It is easy to make three points for supporting the mirror the heads of screws and extend them through the top board to the bottom board and use them for collimation adjustment.

Simple and effective, so what's wrong with it? For a start, the side clips which hold the mirror are not positive enough. If there is too much play between the mirror and clips then the mirror can move around and the telescope will not perform well; or if they are too tight, the mirror could be strained and again the telescope will not perform well. Secondly, if you have ever tried to collimate a telescope with the classic three screws at 120° you'll know it's a right pain. Commercial cells are just as bad. We can do better.

Improvements

The easiest improvement is to change the way the collimation screws operate. Instead of spacing them at 120° so they operate in three independent axes, make one of them a pivot and the other two at right angles to each other as shown on the right of Diagram 1. Adjusting one screw will move the mirror up-down (the X-axis), while adjusting the other screw will move the mirror left-right (the Y-axis). (Of course, one axis needs to be aligned along the same axis as the focuser for the system to work most effectively.) What could be simpler? No longer will collimating the telescope be an exercise in frustration. There is no reason why mirror cells need to be made with a tri-axial collimation system as they are currently. Much professional laboratory equipment is made the way I have described, so why can't makers of amateur equipment do the same? Just make sure that the springs used for spacing the plates are strong enough otherwise problems could occur.

Interestingly, some telescope makers advocate that springs should not be used at all as they can allow the mirror cell to move too freely. Instead they replace each spring with a push-pull arrangement. While this appears to yield a more stable system, I believe that it introduces even worse problems. As you must loosen one of the screws before tightening the other, the system is no longer rigidly held while you make the necessary adjustment. With springs, this unstable situation doesn't occur.



Making your own mirror cell is easy; (top) the author's partially completed cell, and (bottom) ready to receive the mirror.

The other area that needs changing is the way of restraining the mirror. Whatever restraint is used, it must be firm but not constricting. John Dobson attempted one solution by supporting the edge of the mirror with a strap. This is certainly easy on the mirror, but some examples of this design leave out any means of stopping lateral motion of the mirror. I've seen one cell like this that was so useless it allowed the mirror to move

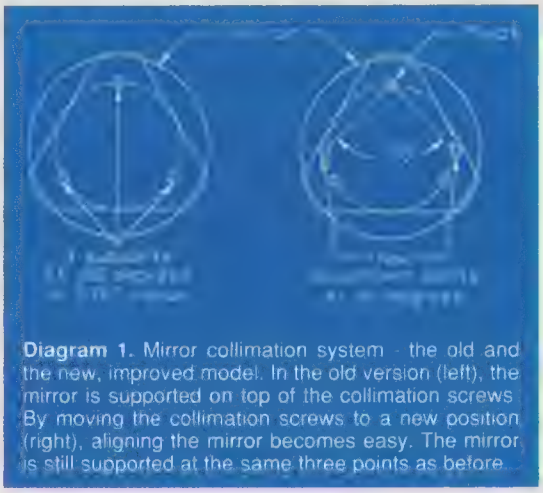


Diagram 1. Mirror collimation system - the old and the new, improved model. In the old version (left), the mirror is supported on top of the collimation screws. By moving the collimation screws to a new position (right), aligning the mirror becomes easy. The mirror is still supported at the same three points as before.

Diagram 2. One of 3 edge supports for the mirror.

out of alignment each time the telescope was moved to a new object! However, even if done properly this design won't work with an equatorially mounted telescope; we need something better.

The answer is to use rigid support posts each with positive screw adjustments onto the mirror. This is shown in Diagram 2. The screws are each slowly adjusted to just touch the mirror and then its lock-nut tightened to hold it there. The tips of each screw should be covered with a blob of solder. Soft and yet rigid, solder is excellent to use where optical elements must contact metal, and where movement is not allowed. Using nylon or other similar pliable material could allow the mirror to move as it compresses or expands under a changing load. Remember that these screws only just touch the mirror; they should not exert any force that could distort it.

Finally, on top of these posts are screwed clips to hold the mirror should it be inverted. They can be lined with cork or any soft material as they don't actually hold the mirror in a fixed position, they just stop it from falling out if it ever gets turned upside-down.

A home-built cell

Let's look at some examples of better mirror cells. We'll start with a home-built one designed from scratch. This cell is for a small (125mm) plate-glass mirror. I used aluminium plate for lightness, using whatever pieces I found in my junk box. A 6mm thick plate for the bottom, 4mm for the top plate, and pieces of right-angle aluminium for the brackets. The first photograph (top left) shows the pieces ready for final assembly.

The bottom plate was carefully cut and filed to fit the tube, in this case 152mm diameter. A small hole drilled through the plate serves as a centre marker. Three right-angle brackets were then bolted on, to attach it to the tube. By making the base plate exactly the same diameter as the tube, it will help the tube remain rigid during use.

The top plate also has a small hole drilled to define its centre. The plate is about the same diameter as the mirror it is intended to carry, although no great care is needed here as exact alignment is done through adjusting screws. I then made brackets to hold the mirror. These were 4mm right-angled aluminium, thick enough to drill and tap for the radial adjustment screws. The screws which hold these on would also be used as the suspension points for the mirror. This is quite a light mirror, so only a 3-point support is needed. Once the top plate was assembled, the brackets could be marked out for the radial adjustment screws and top restraints. The radial adjustment screws are positioned at mid-mirror height. Here, I transgressed my earlier statement about not using nylon to define the mirror position. This mirror is so small and light that the nylon screws will adequately hold the mirror (however, if I were to use this telescope for photography or as a guide-scope then I would not risk using nylon screws).

The top restraining brackets again are small pieces of right-angled aluminium. Cut to just go over the mirror, they are lined on the underside with a thin piece of cork and held to the main brackets with small screws and nuts. Slots in the brackets allow for precise positioning relative to the mirror surface. They can be seen in the photo of the finished cell.

With the top and bottom plates ready, they then need to be joined. I held the two plates together with a small screw through their centre holes and, with the help of a set-square, marked out where the collimation bolts would go. The holes were drilled with the plates joined, ensuring correct alignment of the holes. The bottom holes were enlarged slightly to allow for movement while collimating. In this cell, I had to shorten one of the mirror posts to allow room for the collimation bolt.

It's then a matter of giving it a coat of matt black paint and re-assembling it. The brackets are attached to their respective plates, then the collimation bolts are locked in place by a nut underneath the top plate. The springs slip over the bolts and the bottom plate is then attached. The springs should all be well compressed so that there is no chance of any unwanted movement between the plates.

Modifying a commercial cell

If you don't want to make one totally from scratch, you can easily modify a commercial cell. (It is amazing to think that this needs be done at all, but I have yet to see a commercial cell that satisfies all my requirements.) There are advantages in starting with a commercial cell; they are usually made from cast aluminium and will have a better strength to weight ratio than one made entirely from solid pieces of aluminium or timber, and will generally be more open and so allow freer air circulation around the mirror.

The photo below shows a commercial cell for a 20-cm mirror prior to modification. It uses the simple system of extending the three collimation screws through the top plate for the mirror to sit on. The two plates are separated by strong springs, so we don't need to change these. The first modification, to allow collimation in a sensible coordinate system, will probably only take ten minutes and cost two screws and nuts.

Firstly, completely dismantle the cell. You'll then need to work out where to drill two (or perhaps three) new holes. I was able to use one of the original holes

A modified commercial mirror cell has advantages. The author took a bought unit (top) and improved it with a just few holes and bolts.

(and screws) as the pivot point so I only needed to drill two new holes; I used a set square to help align them. It doesn't matter exactly where the new holes are, so long as they form a right-angled triangle with the pivot. The further apart they are, the finer the adjustment possible. Drill one plate first and then use it as a template for the other, this way the holes are sure to line up. Drill slightly oversize holes in the bottom plate to allow room for movement of the plate during collimation. The final photograph shows the two new holes in this cell. I filed the tops of the two screws in the new holes a little so that they can't touch the underside of the mirror and interfere with the 3-point support.

All that remains is to put two new screws in the old holes for the mirror to rest on. I used screws from my junk box, adding washers underneath to make sure that they were the same height as the pivot screw. The mirror rests directly on the tops of these screws, so I placed small blobs of solder on their tops.

The second modification will take longer and depends on how good the cell is in the first place. This cell needed three completely new edge restraints to be made which took me a few hours to do. The original restraints were nothing more than strips of bent steel. They were strong enough to hold the mirror, but lacked any form of adjustment to allow for variation in mirror size, and could possibly introduce strain in the mirror.

The final photograph shows the new restraints in position. They are made from 6mm thick aluminium and are strong enough to hold the 20cm diameter mirror firmly in place. Coarse vertical adjustment is by slots (the same as the original system). The top mirror restraints are cork-lined washers with their own adjusting screws. They can be positioned to almost touch the mirror, but exert no pressure under normal operating conditions. It is only when the mirror is brought past vertical that the clips apply any pressure to the mirror.

Mid-way up each restraint is a hole, threaded for the solder-tipped screw and lock-nut. I used M4 screws out of my junk box, but almost any size within reason will do. Once in place, each screw is turned until it just touches the mirror and then the lock-nut applied. The result is a mirror that can't move but is not stressed in any way.

Bigger cells

There is some sense in John Dobson's strap support system for large mirrors. Holding the mirror by a large area spreads the load and minimises the risk of introducing distortion. Unfortunately, this design is inherently weak, and also can't be used for an equatorially mounted telescope. So for large mirrors, just extend our design. Instead of just three restraining posts, make a complete ring around the mirror and place a dozen (or more) screws around the periphery. There is nothing magic about using three screws in this situation, any number will do. Remember that these screws only take a small portion of the load of the mirror. Most of the weight still rests on the three (or 9 or 18 etc.) points at the bottom of the mirror.

Conclusion

I once asked one amateur why he preferred to pay a small fortune for a small refractor instead of getting a larger Newtonian. He replied that Newtonians needed frequent TLC and refractors didn't. I looked at him quizzically. He pointed out that all the astronomy magazines and books were full of ways to collimate Newtonians because it was an essential aspect of owning one.

He is right; collimation plays an important part in any telescope - but equally so be it reflector, refractor or catadioptric. I explained to my friend that any badly made telescope would always need attention, but if properly made then they seldom require any attention. You would hope that having paid $3,500 for a 100mm telescope, the manufacturers would provide a cell that doesn't go out of adjustment every time you look sideways at it. I told him that my Newtonians are collimated only once every few years after the mirror is aluminised; a process which takes only a few minutes. Badly built telescopes, particularly the mirror cells, will require frequent TLC, but if you follow the above examples then you can have a trouble-free Newtonian. S&S

Steve Lee is a telescope operator and computer programmer at Australia's largest telescope, the Anglo-Australian Telescope at Siding Spring Mountain, and is an accomplished telescope maker.

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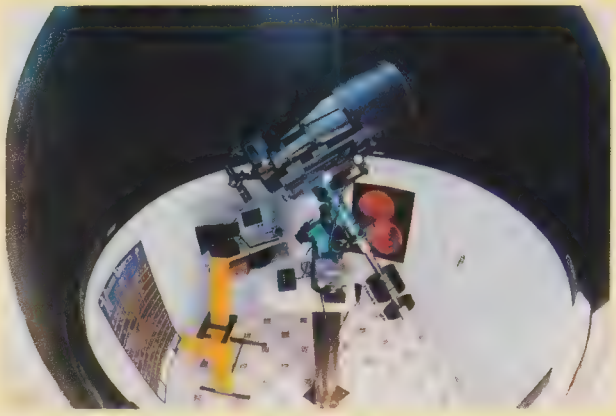

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100,000 out . . .

Space missions have given a few people a special view of the Earth. Astronaut Michael Collins wonders what our world would be like if we all could share that view . . .

I really believe that if the political leaders of the world could see their planet from a distance of, let's say, 100,000 miles, their outlook could be fundamentally changed. That all-important border would be invisible, that noisy argument suddenly silenced. The tiny globe would continue to turn, serenely ignoring its subdivisions, presenting a unified facade that would cry out for unified understanding, for homogeneous treatment. Earth must become as it appears: blue and white, not capitalist or communist; blue and white, not rich or poor; blue and white, not envious or envied.

I am not a naive man. I don't believe that a glance from 100,000 miles out would cause a Prime Minister to scurry back to his parliament with a disarmament plan, but I do think it would plant a seed that ultimately could grow into such concrete action. Just because borders are invisible from space doesn't mean they are not real - they are and I like them. I feel just as thankful today that I live in the USA as I did before flying in space, and I have no desire for this country to merge into a United States of the World.

What I am saying, however, is that all countries must begin thinking of solutions to their problems which benefit the entire globe, not simply their own national interest. The smoke from the Saar Valley may pollute half a dozen other countries depending on the direction of the wind. We all know that, but it must be seen to make an indelible impression, to produce an emotional impact that makes one argue for long-term virtues at the expense of short-term gains.

I think the view from 100,000 miles could be invaluable in getting people together to work out joint solutions, by causing them to realize that the planet we share unites us in a way far more basic and far more important than differences in skin colour or religion or economic system. The pity of it is that so far the view from 100,000 miles has been the exclusive property of a handful of test pilots, rather than the world leaders who need this new perspective, or the poets who might communicate it to them.

Of course, we could always pass out whole-earth photographs and have everyone study them and, if there is any truth in my 100,000 miles premise, the results would be the same. Unfortunately, it doesn't work that way. Seeing Earth on an 8-by-10 inch piece of paper, or ringed by the plastic border of a television screen, is not only not the same as the real view, but even worse - it is a pseudo-sight that denies the reality of the matter. To actually be 100,000 miles

out, to look out four windows and find nothing but black infinity, to finally locate the blue-and-white golf ball in the fifth window, to know how fortunate we are to be able to return to it - all these things are required, in addition to merely gauging its size and colour. While the proliferation of photos constantly reminds us of Earth's dimensions, the photos deceive us well, for they transfer the emphasis from one Earth to the multiplicity of reproduced images. There is but one Earth, tiny and fragile, and one must get 100,000 miles away to appreciate fully one's good fortune in living on it.

If I could use only one word to describe Earth as seen from the moon, I would ignore both its size and colour and search for a more elemental quality, that of fragility. Earth appears fragile above all else. I don't know why, but it does. As we walk its surface, it seems solid and substantial enough, almost infinite as it extends flatly in all directions. But from space there is no hint of ruggedness to it; smooth as a billiard ball, it seems delicately poised in its circular journey around the sun and, above all, it seems fragile.

Once this concept of the apparent Earthly fragility is introduced, one questions whether it is real or imagined and that leads inexorably to an examination of its surface. There we find things are very fragile indeed. Is the sea water clean enough to pour over your head, or is there a glaze of oil on its surface? Is the sky blue and the clouds white, or are they both obscured by the yellow-brown airborne filth? Is the riverbank a delight or an obscenity? The

difference between a blue-and-white planet and a black-and-brown one is delicate indeed. We rush about like busy ants, bringing immense quantities of subsurface solids, liquids and waste gases which lie on or just above the surface as unholy evidence of our collective insanity. The entropy of the planet, its unavailable energy, is increasing at an alarming rate; the burning of fossil fuels is an irreversible process and can only be slowed down. At the same time, the sun shines on us whether we like it or not; yet we are making feeble efforts to focus this energy for our use. For that matter, the sun's energy, which is produced by converting hydrogen into helium, can probably be duplicated by creating our own little thermonuclear reactors here on Earth, if we ever put enough effort into the attempt.

These problems and their solutions are becoming increasingly well known, and I'm sure they would have been recognized had there been no space programme. But anyone who has ever viewed our planet from afar can only cry out in pain at the knowledge that the pristine blue and white one can still close ones eyes and see, is an illusion masking an ever more senseless ugliness below.

The beauty of the planet from 100,000 miles out should be a goal for all of us, to help in our struggle to make it as it appears to be. S&S

Astronaut Michael Collins was Command Module Pilot during the Apollo 11 mission to the Moon. This essay is an extract from the new book, The Greatest Adventure*; originally published in Collins' book* Carrying the Fire.

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IN ORBIT by Kerrie Dougherty

In 1971 and 73, the Russians placed two roving vehicles, Lunakhod 1 and 2 on the Moon. There are also plans for a future Russian roving vehicle to explore Mars during the now-delayed Mars 96 mission. But did you know that the former Soviet Union also put two additional, unsuccessful rovers, into space? In a recent interview, Valery Gromov, Laboratory Chief of the Russian Mobile Vehicle Engineering Institute, revealed that a small rover was launched to Mars in 1971 (aboard Mars 3), but contact was lost with it when it reached the martian surface. There was also a mini-rover on board one of the Phobos probes, intended to explore the surface of the tiny martian moon. This rover was prevented from landing because of the failure of its parent probe.

Mars 94 and 96 delayed

Following on from the loss of the US spacecraft, Mars Observer, the detailed exploration of Mars will be set back still further, with notification that the Russian Mars 94 and Mars 96 missions will be delayed.

The Russian-led missions were the subject of speculation for some months. The Mars 94 spacecraft, which includes an orbiting section and penetrators which will dig into the Martian surface, is behind in its construction schedule. The cash-strapped Russian Space Agency had been seeking financial contributions from the 20 other nations participating in the mission, in order to keep the programme on track. Part of the difficulty lies in the fact that financial problems have delayed payments to Russian contractors, many of whom will not work on a project without up-front payment to offset the effects of Russia's high inflation rate.

The decision to delay Mars 94 means that the originally-planned Mars 96 mission will be pushed back to 1998, when another launch window will be available. Mars 96 is intended to land a small roving vehicle on the martian surface, as well as releasing a French-designed exploration balloon.

NASA, meanwhile, has yet to fund a replacement for Mars Observer and seems prepared to move directly onto its Mars Surveyor programme, a ten-year study of Mars which is intended to send seven spacecraft to the Red Planet between 1996 and 2005. The first two missions in the series, the Mars Global Surveyor and Pathfinder are due for launch in 1996 (which, with the postponed Mars 94 mission, will make it a bumper year for Martian exploration). The Global Surveyor, due for launch in November 1996, is designed to gather much of the information originally intended to be obtained by Mars Observer. Its primary goals will be to provide a comprehensive map of the martian surface, provide information on potential landing sites for future missions, and act as a relay station for missions on the planet's surface over the ensuing five years. The Pathfinder mission, due for launch in December 1996 will place a mini-rover on the martian surface, together with three cameras to provide imagery.

***Below:** Mars - the closest planet, but we're still a long way from returning to it.*

The day the Sky(lab) fell

July marked not only the 25th anniversary of the first Moon landing, but also the 15th anniversary of the 'crashdown' in Western Australia of Skylab, the first American space station. Originally occupied by three crews of astronauts during 1973 and 1974, NASA intended to re-occupy the massive space station (adapted from the third stage of a Saturn 5 rocket) and maintain it in its orbit by using the Space Shuttle as a tug and resupply vehicle.

However, the Shuttle's completion was greatly delayed and this meant that NASA had no way to reboost the space station before its orbit decayed more rapidly than expected, due to higher than anticipated sunspot activity. In July 1979, NASA controllers attempted to bring the massive spacecraft down in the Indian Ocean, but when Skylab did not break up as expected on re-entry, its descent path was altered. Although most of the space station did fall into the Indian Ocean, the night of July 11-12 saw a rain of debris fall in Western Australia, along a swath stretching from Esperance, in the south, to the area around Balladonia and Rawlinna on the Nullarbor Plain.

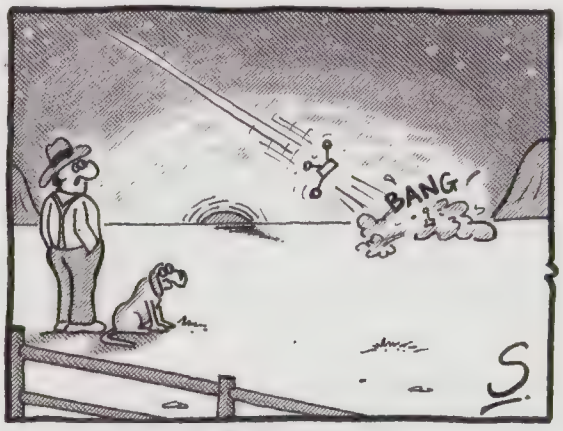
Fortunately, there were no injuries or property damage as a result of the crash-down. Souvenir hunters and budding space entrepreneurs quickly salvaged much of the crashed space station; a story about the fate of many of these pieces of space debris will feature in an issue of SKY & SPACE later this year.

Clementine - Lost Forever?

Despite the completion of its Moon mapping phase, the Clementine spacecraft will be unable to complete the rest of its mission, due to a malfunction which caused the loss of its manoeuvring fuel.

After successfully completing its Moon mapping mission in mid-April, Clementine left lunar orbit on May 3, to commence the second stage of its mission, which was to have seen the spacecraft flyby the asteroid 1620 Geographos in late August. On May 7, a computer malfunction caused Clementine to fire its attitude thrusters continuously, thus depleting their fuel supply. As a result, Clementine, while still functional, began spinning at a rate of 80 revolutions per minute, which prevents its camera from gathering images properly. The cause of the mishap is as yet unknown, but an error in Clementine's complex software is believed to have been the problem.

Clementine's controllers attempted to reduce the spacecraft's spin rate by firing its main engines, which still have fuel. Although they were able to reduce the



spin rate to 30 revolutions per minute, this is still not slow enough to permit adequate imaging. It was also found that Clementine's sensors were no longer pointing in a direction that would enable it to obtain a view of Geographos during the flyby. Consequently, the mission to asteroid Geographos has been cancelled. Instead, Clementine will be re-inserted into Earth orbit to allow its lightweight sensors to be tested in the hard-radiation environment of the Van Allen radiation belt.

Despite this setback, the spaceprobe's Moon mapping mission was highly successful. It has provided the first comprehensive look at the lunar surface under consistent lighting conditions and 11 different wavelengths. During its survey of the Moon, it transmitted 25,000 images per day to its small mission control centre at the Naval Research Laboratory.

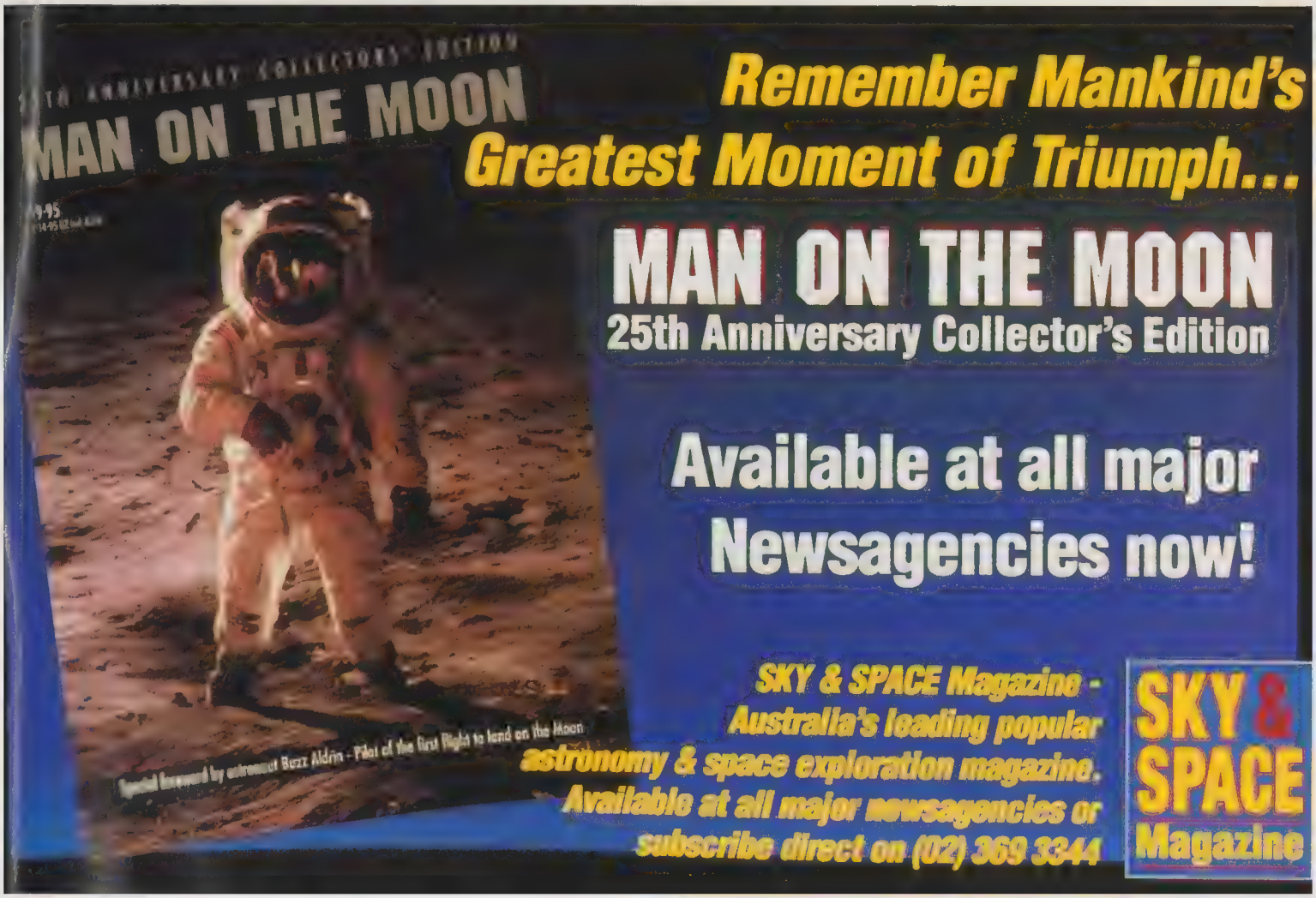
Perusing Pluto

The last planet still unexplored in the Solar System, Pluto has been the subject of discussions between NASA and the Russian Space Agency, on developing a co-operative mission to explore it and possibly also its moon, Charon. The preliminary proposal is to use US spacecraft, possibly launched by Russian Proton rockets, to crash land small Russian-supplied instrument packages onto the surfaces of Pluto and Charon. These Pluto-zonds could hold equipment to image the planets' surfaces and conduct chemical analyses of their atmospheres.

The Russian/American proposal is in addition to the Pluto Fast Flyby mission, already under development (though not yet fully funded) at NASA's Jet Propulsion Laboratory. This mission would launch two lightweight spacecraft on fast trajectories that would take only ten years to reach Pluto. This mission is planned to investigate the atmosphere of Pluto while it is still gaseous, during the planet's pass inside the orbit of Neptune.

The Pluto Flyby may even be combined with the Russian proposal as a way of cutting costs and bringing the mission in at the $400 million price tag that NASA head, Dan Goldin, has placed on the programme. S&S

Kerrie Dougherty is Curator of Space Technology at Sydney's Powerhouse Museum, home of Australia's first permanent space exhibition. She is co-author of the book, Space Australia.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METEOR DIARY by Jeff Wood

Meteor observing is a fun and inexpensive way to enjoy your hobby. So get out your charts and pencils, and get ready to catch some meteor showers.

As periodic comet Swift/Tuttle started once again to swing through the inner solar system a couple of years ago, meteor observers began to predict greatly enhanced activity of the 1993 Perseid meteor shower. Swift/Tuttle is the parent comet of the Perseid meteor stream.

The predictions were widely publicised in the media, leading to wild speculation that meteor rates of thousands per hour would be seen. Unfortunately, the media did not take into account that this was only a possibility, not a certainty, and also that the Perseid radiant (the point in the sky from which meteor showers seem to spread out) was on or below the northern horizon for most Australian observers.

The International Meteor Organisation (IMO) sponsored a world-wide observation programme during the 1993 shower, enlisting the aid of hundreds of observers in 28 countries. The first overall results have now been compiled and indicate that a meteor storm did not eventuate. Although this was a bit disappointing, the Perseids did produce their normal display of about 100 meteors per hour (zenithal hourly rate).

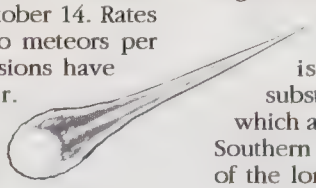
In Australia, much of the southern half of the country was affected by a low pressure/cold front system that prevented all but a few observations being made here. However, the northern half of Australia fared better and some good results were obtained by Robert Barber and Geoff Price (Exmouth) and Simon Tonkin (Townsville). Observing skies with a limiting magnitude of 6.0, Simon recorded the best Perseid rates of 17 meteors per hour from 4.30 to 5.30am local time on the same night. The best rates from southern Australia - five meteors per hour - were recorded on the same night by your author at Yorkrakine, WA, under partially cloudy skies and a limiting magnitude of 6.7. At Yorkrakine the radiant was only a couple of degrees above the northern horizon.

The 1993 Perseids produced plenty of bright, yellow meteors with trains.The most spectacular meteor recorded was a magnificent -4 yellow fireball that left a train for some 30 seconds after the meteor itself disappeared from view.

Meteor showers

Following the excellent meteor activity of recent months, meteor observers tend to feel a little let down when conditions return to normal during September and October. But there are a number of interesting meteor showers to watch for (see table), and I'll cover a few of them here.

The **Southern Piscids** is a weak ecliptic stream, active from the middle of August through to October 14. Rates are generally one or two meteors per hour, but on some occasions have reached five per hour. Maximum occurs on September 21, which means it conflicts with the full Moon (September 20). It's therefore best to look for this shower before and after maximum.



The κ-**Aquarids** is a minor ecliptical stream which has an activity period of September 8 to 30, reaching a maximum on September 22. Since its period of activity and radiant are similar to the Southern Piscids, both showers can be observed simultaneously.

The **October Capricornids** were discovered in 1972 and provide variable activity from year to year, reaching a maximum on October 3 with dark, moonless skies.

The σ-**Orionids** shower is active from September 10 through to October 26. Its maximum hourly rate of three, occurs on October 5, which means that the light of the Moon does not interfere this year. The σ-Orionids have their radiant in the Belt of Orion; observers should watch during the last few hours before sunrise and centre their field of view no more than 30° west or north-west of the radiant.

The **Orionids** is a major shower which, unfortunately, has unfavourable moonlight conditions this year. They have a complex radiant structure with the centre of activity located just north of the star Betelgeuse at maximum. The Orionids are associated with Comet Halley and, like the η-Aquarids, display a plateau-like maximum - generally from October 20 to 25. Orionids are best observed during the latter part of the night when the radiant is more than 20° above the horizon.

The **Taurids** meteor show is broken up into several substreams, the most important of which are called the Northern and the Southern Taurids. The Taurids have one of the longest activity periods known, lasting from September 13 through to December 1. They reach a broad maximum in late October and early November. In September and October, the Taurids are best observed during the middle and latter parts of the night. They are noted for their many fireballs which are frequently yellow and orange in colour, but all of the other colours are also well-represented.

Take advantage of the longer nights and warmer weather. Meteor watching can be a fun and very inexpensive addition to your other astronomical pursuits. S&S

Meteor showers for you to observe

Meteor shower	Date range	Maximum	Radiant RA	Radiant Dec.	Hourly Rate
Piscids S	Aug 15-Oct 14	Sep 21			
κ-Aquarids	Sep 08-Sep 30	Sep 22			
Capricornids (Oct)	Sep 20-Oct 14	Oct 3			
σ-Orionids	Sep 10-Oct 26	Oct 5			
ε-Geminids	Oct 14-Oct 27	Oct 20			
Orionids	Oct 02-Nov 07	Oct 21			
Taurids S	Sep 15-Nov 26	Nov 03			
Taurids N	Sep 13-Dec 01	Nov 13			
Puppid/Velids	Oct 15-Jan 22	Several			

Jeff Wood is an accomplished meteor observer based in Perth. He is one of only two Australians on the board of the International Meteor Organisation, and acts as a coordinator for meteor observing throughout Australasia.

If you want more information about meteor observing, you can write to me at the following address:
Jeff Wood, IMO
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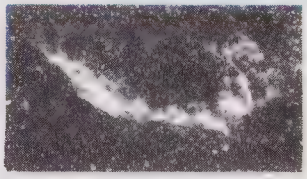

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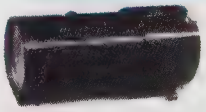

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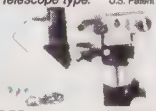

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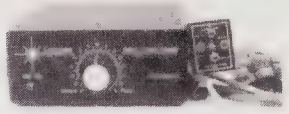

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South Australian amateur, Andrew Peters, is an expert in the art of deep sky photography. He describes his equipment set-up, and gives us his hints and tips for taking better astrophotos.

A rented farm house on 160 hectares in the northern Mt Lofty Ranges, some 200 kilometres north of Adelaide has become my ideal site. Elevation is 488 metres, while a dirt road leads to the summit of Mt Bryan, itself some 976 metres high. The site is sufficiently far north of Adelaide to leave most of the poor weather behind. With an annual rainfall of only 40cm, the site enjoys 33% cloud-free days per year.

The skies here are velvet black with transparency extending to the horizon. The skies easily rival Siding Spring. With no interfering street lights or car headlights, four-hour exposures at f/9 exhibit no fogging!

The incredible contrast enables the telescopes to work at the limit of their capabilities. The views of deep sky objects through the 50cm are better than the views seen through much larger 'scopes at lesser sites. Faint images seem to leap out of the eyepiece.

My photographic set-up is very versatile. The 15cm refractor rides piggy-back on the 50cm and acts as a superb guidescope/finder and photographic instrument. Images are razor sharp. The 50cm is reserved for faint, small objects.

Below: *The author's observatory in the hills north of Adelaide. The shed rotates, giving a clear view in any direction through the door, plus the roof opens to allow access to the sky overhead.* ***Right:*** *The author next to his 50cm telescope.*

A coma corrector is used to flatten the field across the entire 35mm frame.

Wide-field photos are taken with the Byers mount sitting on a pre-aligned pier in the backyard. Recently a 10cm Genesis refractor has been added to the family. It is compact and light-weight, making it very portable. Its sharp optics and fast, f/5.4 focal ratio make it a superb instrument for wide-field shots.

In 1992 I purchased an ST-4 auto-guider. It is simply the best accessory I have owned in the last 10 years. It guides the larger 'scopes, freeing me to do visual work or wide-field photography with the other mount. It certainly takes the drudgery out of guiding and allows the photographer to enjoy their hobby. Photographic sessions begin at dusk and end at dawn thanks to this device.

The only dilemma I now face is deciding which instrument to use on the next photographic target!

Choose your film with care!

Your photos will never have the impact they deserve if they are not shot on fine grain film. For black and white work hypered 2415 reigns supreme. For colour work, Ektar 25 is the best. Its extremely fine grain allows enlargements to mural size, while its excellent red sensitivity makes it ideal for nebulous objects. Like 2415, its relative speed gain is higher than other hypered films. Furthermore, its colour balance is little affected by the hypering process and it suffers less from

reciprocity failure than any other hypered film I have tried. For those with fast photographic systems or who are prepared to guide for long periods, this is the film to use.

The old Fuji Super HG emulsion is my second choice. It exhibits good blue and red sensitivity but lacks the crispness and resolution of Ektar 25. For slide work hypered Fujichrome Velvia is a good choice and Ektachrome 400 works well with cold cameras. If anyone knows of other films to use with dry ice, please drop me a line.

Align your 'scope

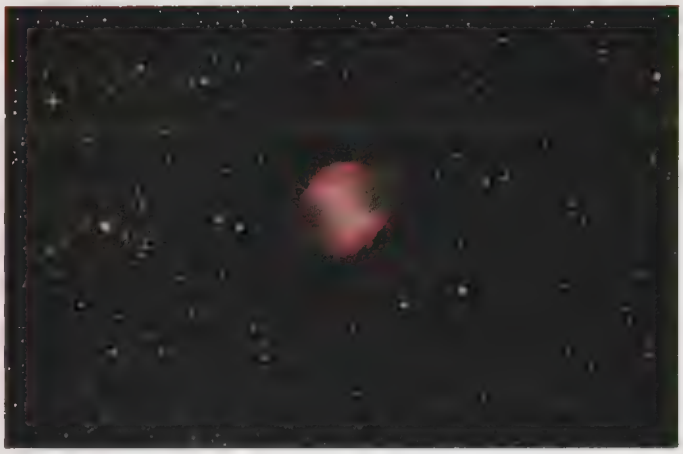
There can be no excuse for a poorly aligned telescope. A pre-aligned pier/wedge at your favourite dark sky site will prevent you losing your alignment when dismantling your equipment. The time saved can be productively used planning the night's work.

For those guiding manually it is essential to have as high a guiding ratio as possible. A camera body attached to the focuser gives an image scale similar to a 50mm eyepiece. Thus a 12.5mm eyepiece placed in an off-axis guide will give a 4:1 guiding ratio. This is not high enough! A 2-3x barlow is essential.

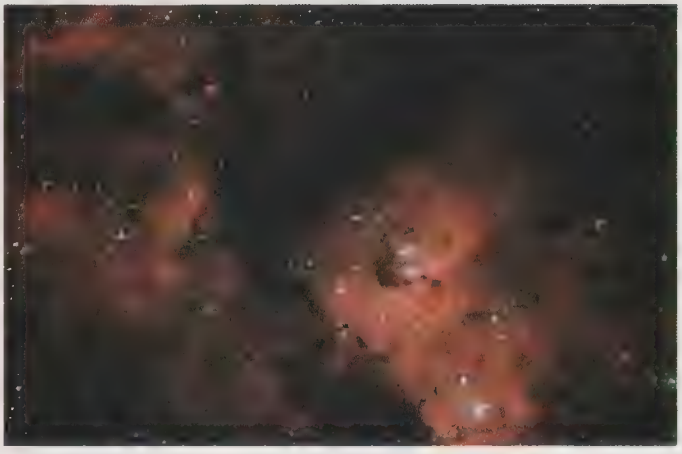
The use of an off-axis guider will prevent differential deflection. Separate guidescopes seem to work satisfactorily only for short exposures, which means fast grainy films (yuk). My experience has also shown that the combination of refractor guiding another refractor seems

Left: *Galaxies M65 and M66 in the constellation Coma. Photographed using a 50cm f/5 telescope, coma corrector, ST-4 autoguider and hypered Fuji 400 film; 90 minutes exposure.*

Top right: *M27, the Dumbbell Nebula, in the constellation Vulpecula. Photographed using the same set-up as the galaxy photo at left, but with 60 minutes exposure. All photos by the author.*



Right: *The Eta Carina Nebula. Photographed using a 50cm f/5 telescope, plus coma corrector, on hypered Ektar 25 film; 60 minutes exposure.*



to work better than if it was guiding a reflector (for long exposures).

I find an illuminated reticle with double crosshairs easy to use. With a 10x guiding ratio, keeping the guide star anywhere in the box produces round star images.

Needless to say, the more accurate the drive system the better. This is especially true for long-focus instruments and for long exposures where fatigue will set in. The second item ordered after my primary mirror was a 38cm drive. Say no more.

Guide star selection can be easy if you know how your equipment works. Once the subject is centred in the camera viewfinder, you need to know exactly where in the field of view the off-axis guider is picking up a guide star. With my set-up the guide star is just outside the camera viewfinder along the major axis. Hence, moving the subject north, south, east and west from the centre quickly shows where the brightest guide star is. This can save considerable time.

Left: *The southern peculiar galaxy, NGC 5128, known to radio astronomers as Centaurus A. A 140-minute exposure on hypered Ektar 25 film, using the 50cm telescope.*

The perfect photo

The knife-edge focusing method is the only reliable way to avoid 'soft' focusing problems. I had a machine shop make an adaptor that duplicates the distance from the back of the off-axis guider to the film plane. A strip of audio tape glued to a clear piece of glass is placed at the end of the adaptor. A bright star is found and the 'scope is moved in RA or Dec. A dark curtain will appear to cut across the image of the objective from the opposite direction to which the telescope is moved. The curtain effect will not darken the entire objective if the focus is slightly out. Focus is adjusted until the objective appears to darken simultaneously. Focus is then perfect. Always refocus after every photo.

Never shoot a whole roll of film in one night. I only hyper four or five frames at a time and aim for two or three photos per night. It is better that you nail two good photos than trying to get half a dozen mediocre ones. Otherwise you'll only have to re-shoot them.

Take the time to develop a working relationship with a photo lab if you are not doing your own processing. Presenting example photos and offering to pay for the test prints is looked upon positively. Always ask to speak to the person who will actually be doing the printing.

Photography can be a richly rewarding pastime or can be very frustrating. Everything depends on how much attention one pays to the fundamentals. The more you increase the odds in your favour the better. So no matter what your level of interest may be, or how basic your equipment is, load those cameras and just do it. And above all else, enjoy. S&S

Andrews' superb photos have featured regularly in our Readers' Photos section.

Reviews

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Thomas Arny is Associate Professor of Physics and Astronomy at the University of Massachusetts, USA. This book is intended primarily for American college students, but would greatly interest the serious amateur astronomer.

Explorations is mainly concerned with the how and why of astronomical phenomena. It provides information on, for example, why the Moon makes two tidal bulges on the Earth, how interstellar dust affects our observations of the Milky Way, and the methods by which the distances to stars are measured. Topics of the chapters include: telescopes and instruments, the Earth, the Moon, the solar system, individual planets, the Sun, the Milky Way galaxy, measuring the properties of stars, stellar evolution, galaxies, cosmology and the history of astronomy.

The book is very clearly written, starting with basics. Its clarity is enhanced by the large number of illustrations - there is at least one figure or diagram on every page. The pictures include some taken by David Malin with the Anglo-Australian Telescope. The non-mathematical reader can ignore the small amount of mathematics, or leave it for a second reading. At the end of each chapter, there are a brief summary

York Optical Co. announces massive Meade telescope and accessory price drop!

As a result of new negotiations with the US telescope manufacturer, Meade Instruments Corporation, Australian telescope and accessory retailer, York Optical Company, has dramatically reduced the prices of all Meade telescopes and accessories to an unprecedented level. The purchasing power that comes from having three stores nationally, will also help them to keep prices as low as possible. York Optical Company is the official Meade distributor in Australia.

Meade Instruments Corp. have also made available to Australian customers an unbelievable special offer of more than $600 of free accessories with every LX200 Schmidt-Cassegrain telescope purchased. The offer is valid only for a limited time.

'York Optical is committed to continuing to improve customer service and relations,' York's general manager, Klaus Misins, told SKY & SPACE. 'We've appointed two new state managers - Peter Welman in Victoria and Keith Williams in Western Australia - to handle our increasing sales. Peter and Keith are looking forward to meeting past, present and future customers, as is Steve Dyers, our experienced Queensland state manager.' The new state managers have optical-related backgrounds which ably equip them to provide in-depth support for the existing and new range of Meade and other products.

'I invite all SKY & SPACE readers to drop in to any of our three stores and check out our wide range of telescopes and accessories,' said Misins. 'We're there to help you and make we'll make you feel most welcome.' **J.Nally**

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Lunar Terminator. *Single 0.4 second CCD image taken at the prime focus of a C-11 apertured down to 2.5 inches. Courtesy SBIG.*

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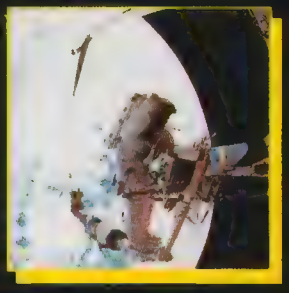

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of the main points, test-yourself questions to challenge the serious reader, and a list of further reading (mostly articles in Scientific American). There is a glossary at the end, explaining technical terms.

I have only a few small gripes. One is that the pages are not numbered in a single sequence - there are interpolated groups of pages with their own numbering, and it is quite time-consuming to locate topics from the index in those interpolated pages.

This excellent book should appeal to the serious amateur and to the undergraduate student beginning studies in astronomy. **Fred Rost.**

Fred Rost is Professor of Anatomy at the University of NSW, and a keen amateur astronomer.

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New releases

Six Roads From Newton
by Edward Speyer
John Wiley and Sons
Hardback, $29.95

Six Roads From Newton is a lively tour through six important theoretical developments in Physics: wave theory, field theory, statistical physics, special relativity, quantum theory, and general relativity. Requiring no advanced mathematics, this book makes all crucial concepts of both Newtonian and non-Newtonian physics extraordinarily accessible to non-scientists, even the mind-boggling world of quantum theory.

The book begins in seventeenth century England with an introduction to Isaac Newton and his laws of space, time and motion. Advancing chronologically, Edward Speyer takes the reader through each of the monumental breakthroughs that have occurred since. He demonstrates how each development has either built on or challenged Newton's work, and in the case of quantum theory, forced a thorough re-examination of even the most basic of Newtonian principles. Speyer provides dozens of real-world examples, as well as a few of the playfully bizarre mind-benders physicists have dreamed up to test their theories, such as The Twin Paradox, The Man in the Elevator, and the deliciously diabolical, Schrondinger's Cat.

In the final chapter, Edward Speyer makes an intriguing foray into the most perplexing moral, ethical, and philosophical 'Big Questions' raised by modern science and speculates on what the future may hold.

The Guide to the Galaxy
by Nigel Henbest & Heather Couper
Cambridge University Press
Softcover, $45.00

Nigel Henbest and Heather Couper, two of the world's most experienced and successful popularisers of astronomy, have combined once again to produce a superb new book, *The Guide to the Galaxy*. The book is written in non-technical language, for the general reader and the amateur astronomer, making it a delightful tour of our home galaxy.

The lucid text is supported by a dazzling portfolio of colour photographs of stars, star clusters and gas clouds in the Milky Way. Specially created maps locate the hundreds of tourist spots visited in this journey through space.

The Guide introduces the nature and structure of our Galaxy as a whole. All types of objects that it contains are then described. These include mysterious black holes, the giant globular clusters of stars, every kind of star, regions of star formation, exploding stars and their remnants and the enigmatic objects at the galactic centre, as well as the giant halo surrounding the Galaxy.

The Guide to the Galaxy includes the latest data and theories on several highly topical areas of research, such as the structure of the galactic halo, new images of the galactic centre, and our latest understanding of stellar evolution. *The Guide* also boasts some of the very latest images taken of deep space. With *The Guide*, Henbest and Couper have produced yet another stylish and easy-to-read book. It's worth buying. **JN.**

If you have a new product or service to promote, or if you've heard of one that you think other readers might like to know about, contact the Editor to arrange its inclusion here. Details in this section are provided by the suppliers: SKY & SPACE is not responsible for any of the information presented.

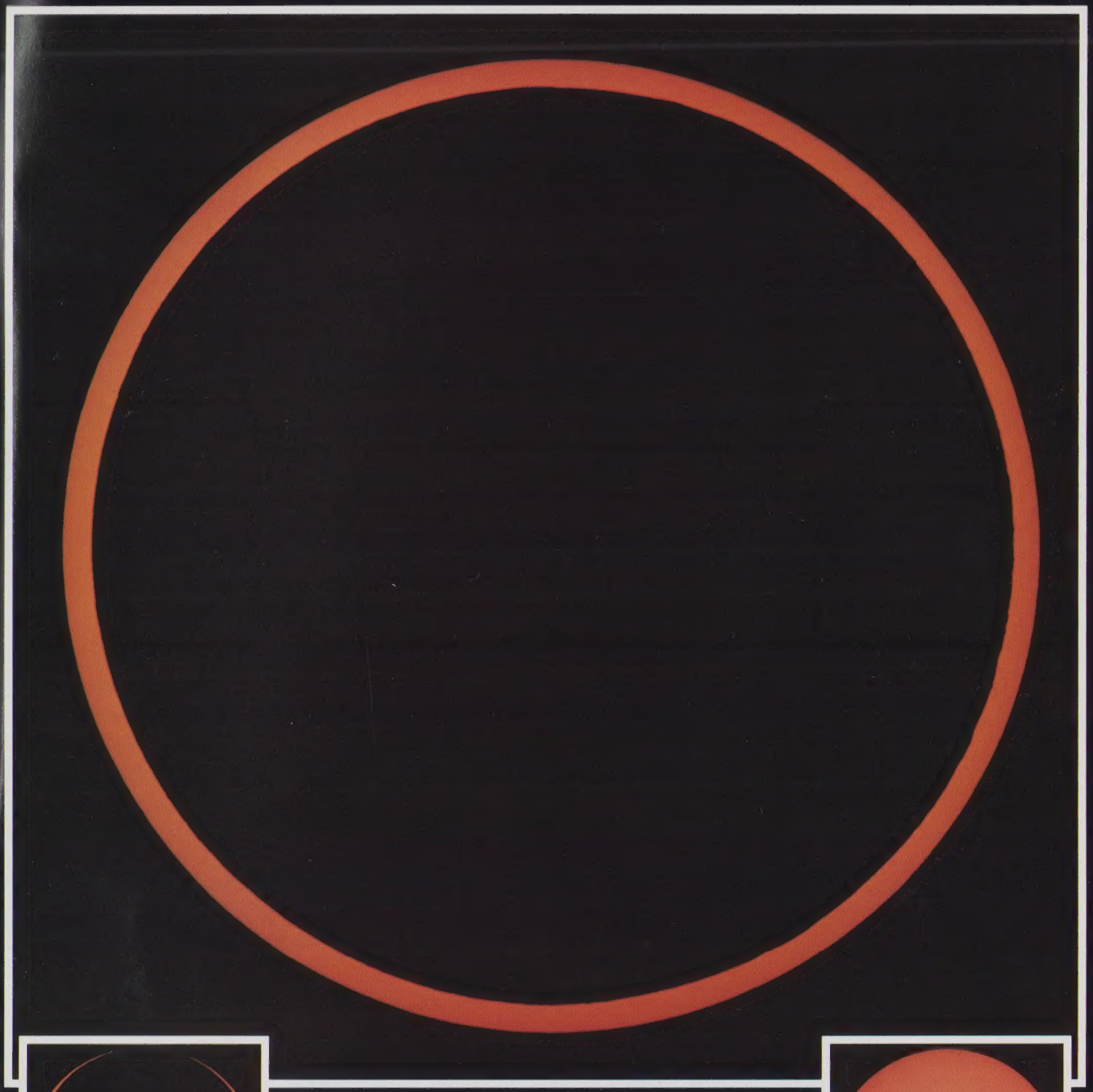
Buy, Sell & Swap

For sale: Telescope, 9-inch Newtonian on Dobson mount. Fully rotatable tube. 2 Orthoscopic and 1 Kellner eyepieces. Telrad finder, Parks mirror and focuser. Novak spider and holder. Deep sky and Moon filters. 3 years old and all in excellent condition. $950 ono. Phone Bob on (047) 240 469 (BH) or (02) 670 5845 (AH).

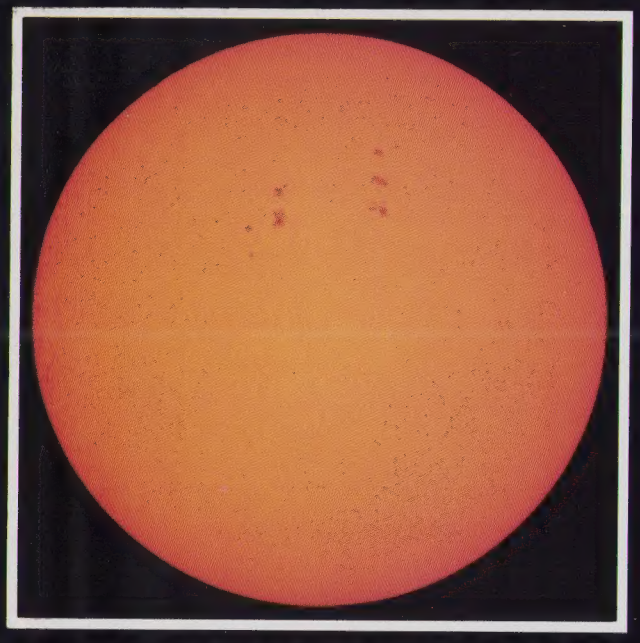
For sale: Celestron 8 with tripod and wedge - as new condition (circa 1989). Also 8x50 finderscope and rings, T-adaptor and other accessories. $2,500. Meade 1000mm mirror lens (in case), f/11, eyepiece, filters, Barlow lens, star diagonal - very good condition. $500. Tasco 50mm binoculars (zoom), 10-22x, in case, good condition. $150. Eyepieces - Celestron 26mm Plossl, 30mm Plossl, 7mm, 12.5mm Orthoscopic. Approx $100 each. Also Parks eyepiece filters (set of 8) and Parks camera mount with slow motion screws - price neg. Ph (02) 290 5674 between 8.00am and 4.00pm.

Entries in Buy, Sell & Swap are free to SKY & SPACE readers - no dealers please. Send to: SKY & SPACE Magazine, Buy, Sell & Swap, 80 Ebley St, Bondi Junction, NSW, 2022. Fax: (02) 369 3366.

Readers' Photos

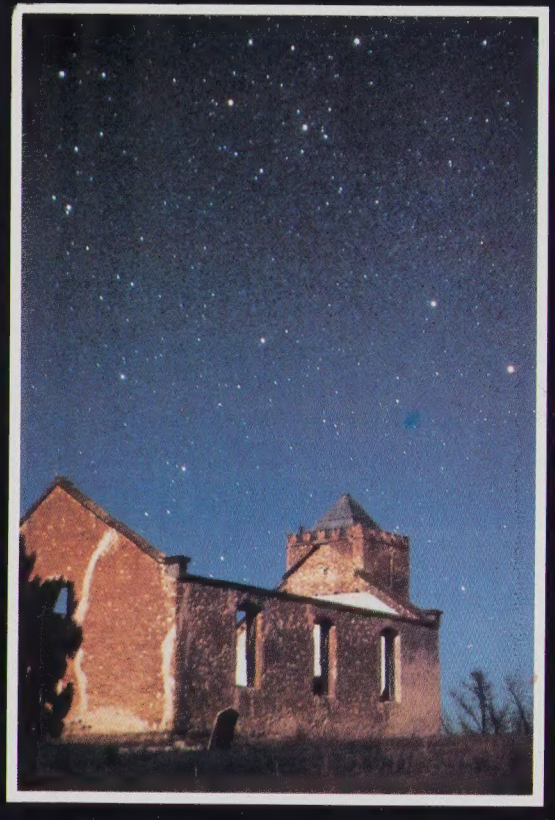


Dan Good is one of our many North American readers, and a devoted eclipse follower - his photo of the July 1991 total solar eclipse made the cover of our November 1991 issue. The photos on this page are of the May 10, 1994 annular solar eclipse. Dan used a 12.5cm f/8 refractor with a solar filter, and Ektar 25 film. Detail of the Moon's edge can be seen in the main photograph.



Above: Ron Knight took this tremendous shot of the sun complete with large sunspot groups, on January 2 this year. He used a Celestron Ultima 8 telescope, Minolta SRT101 35mm camera, mylar filter and Fuji 400 film for this 125th-second shot.

Below: Chris Dunmill's photos have appeared in SKY & SPACE before. Here is another one of his shots taken at the ruins of Ebenezer Mission near Dimboola Vic. The photo was taken at 10.00pm on February 20 using a 50mm lens and 35 seconds exposure on Ektachrome 400 film.



Above: Regular Readers' Photos contributor, Chii-Sheng Lin from Taiwan, took this one-second exposure of the Moon using Fuji Super G400 film and eyepiece projection.

Below: This photograph of the three-day-old Moon and Venus was taken by Bruce Aldam from Nairne, South Australia. Bruce used a tripod-mounted 58mm f/2.5 lens and Fuji 400 film for this 10-second exposure. Note the skyglow from Adelaide, 40 kilometres away on the other side of a mountain range.

Above: Steven Williams, manager of Grove Creek Observatory, took this magnificent shot of the Eta Carina Nebula with a 25cm Takahashi telescope, on Kodak Gold 400 and a 30-minute, hand-guided exposure.

Below: April's Planetary Page inspired Edgar Meyer to photograph Jupiter. Using a 10cm refractor and Kodak TP 2415 film, he took these shots on April 18, at 11.02pm, 11.23pm and 12.08pm respectively.

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The best Readers' Photo published in each issue will win for the photographer $30 worth of astro film from Australian Scientific Films' catalogue. Write your name, address and telephone number clearly on the back of prints or the front of slide holders. Please include a stamped, self-addressed return envelope. The winner will be announced in each issue.

This issue's winner: Edgar Meyer, for his photographs of Jupiter.

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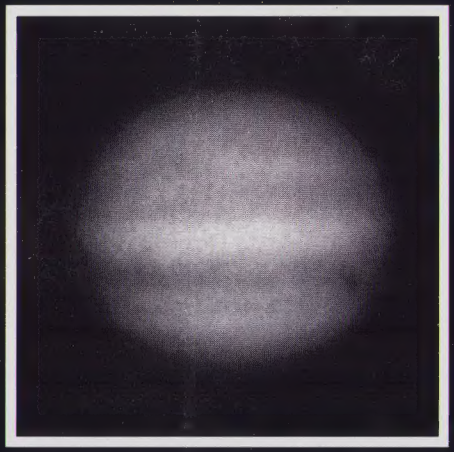

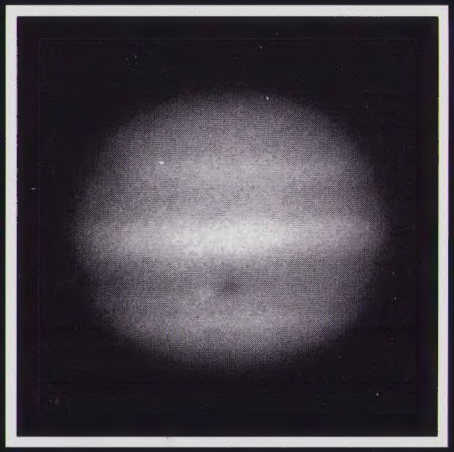

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